FINAL REPORT

NEIGHBORHOOD ELECTRIC VEHICLE MARKET TEST DEVELOPMENT PROJECT

SACRAMENTO ELECRIC TRANSPORTATION CONSORTIUM RA 93-23 PROGRAM

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ABSTRACT

The neighborhood electric vehicle (NEV) niche is the object of this market and product test project. The project availed itself of a limited production three wheel, single passenger low performance NEV designed and produced in Denmark to determine the acceptability of the design for production and use in North America. This vehicle, as well as a prototype four wheel vehicle designed and constructed through this project, are entirely reinforced plastic chassis and body. Pacific Electric Vehjicles was the primary participant in the Project. Included are the evaluation of drive system components, battery charging schemes, body and chassis and glazing material suitability. The project determined and/or verified many of the realities of motor vehicle development and usage in the U.S., which remain more restrictive than elsewhere. Statistical usage data, maintenance requirements, and user experiences are reported and analyzed.

INTRODUCTION

The Neighborhood Electric Vehicle Market and Product Test Development Project (Project) is one of the SETC projects funded as a result of RA 93-23. As such it was a first phase development project to advance known technology.

The primary participant of this Project was Pacific Electric Vehicles (PEV), a northern California company formed to develop electric vehicles (EV), EV products, and be a regional distributor of EVs and related products.

PEV carried out nearly all critical activities of this Project. Nearly all data and other deliverables were a direct result of PEV's concerted efforts to meet the objectives of the Project. Their activities are addressed within reports and other documentation authored by PEV, and will not be reiterated here. Their reports are included as appendices to this cover report addressing all areas of the Project, as Appendices A through JJ. Appendix A is PEV's Final Report for their scope of the overall Project.

OBJECTIVES

<u>Original Project Objectives</u>

The original project proposed to DARPA intended to place 120 of one low performance neighborhood electric vehicle into lease service in the Sacramento area. The vehicle

design was acknowledged as the minimum performance required of any EV user, short of two wheel motorized scooters and bicycles. The large number was intended to be statistically significant and also generate enough lease income to operate the maintenance and test activities of the business responsible for carrying out the product and market test.

The "City-el" was the vehicle proposed for use. Usage, performance and maintenance data were to be collected, and an "Americanized City-el" design was to be the outcome of the project. The following activities were proposed:

- Testing of the local U.S. market acceptance of NEVs currently available;
- Evaluate user performance requirements and other characteristics;
- Evaluate vehicle and component design, performance and reliability;
- Determine design improvements to add product value and expand market acceptance;
- Test different marketing approaches;
- Determine infrastructure requirements and service requirements needed for the vehicle, fuel providers, and the building industry; and
- Create the largest operating U.S. concentration of electric vehicles for potential testing of advanced batteries, motors, controllers, and related systems.

Generally stated in the proposal, "the ultimate goal of the project will be to determine the market potential for NEVs, develop a successful vehicle design and assist the private sector participants in committing to manufacture and sale of such vehicles in the U.S. market without incurring excessive risk."

Many of the original objectives were met very early in the Project, through conclusions reached on the inadequacy of the 3-wheel platform for NEVs. The slow response to the lease program for the vehicles was apparent early on, and therefore helped determine the course for the Project prior to acquisition of a larger number of vehicles.

<u>Objectives of Redirected Project Scope</u>
Following initial marketing, performance evaluation and negative experiences in the City-el vehicles, an accelerated approach to the Project was proposed to DARPA. The number of City-el vehicles was trimmed to 48, a portion of the Project funds were designated for redesign and retrofitting of the City-el canopies, and a significant portion of the Project funds were designated for design and construction of a prototype four-

wheel NEV. As part of the prototype vehicle effort, three City-els were converted to four-wheel designs.

The NEV prototype, the ***Peregrin***, is intended to address nearly all the perceived design weaknesses in the lower performance 3-wheel variety of NEV. It is a major effort to take a vehicle design beyond the prototype stage, and thus the objective of this initial phase of development leads first to consideration of the next steps in development of a motor vehicle intended for use on public streets. The economic and regulatory climate are the primary considerations, with a large number of secondary considerations.

A concise perception of this project could also be stated as establishing the minimum capabilities and performance for EVs in a military base and other non-highway environments. Twenty-five City-el vehicles were placed in service at McClellan AFB. Infrastructure and other support requirements for military installations were a major consideration.

SUMMARY AND CONCLUSIONS

PEV lease program experiences with City-el vehicles

The market test portion of the Project relied heavily on vehicle lease response and specific feedback from lessees. As noted in PEV's Final Report, the shortcomings of the vehicle proved insurmountable and full deployment of all 48 vehicles purchased with DARPA funds was not attained. The maximum number of vehicles in use by lessees was 39 units. Sixty thousand (60,000) miles were, however, logged over the term of the Project, with a significant quantity of data obtained.

For more detailed information on the lease program, refer to PEV's Final Report (Appendix A), Sections 3.2 and 3.3

Military Oriented Experience

Of particular interest is infrastructure requirements for vehicles on military bases. An early option that was suggested to McClellan's EV Program was to use as many existing power sources on base as possible. The level of expenditure to support low performance EV charging was thought to be significantly less than for other EVs.

Soon after placement of vehicles in the control of users, the need for convenient charging receptacles was an issue in most of the base locations. The time and access requirements for using long cords for charging on existing electrical circuits was unacceptable. Additional circuits were installed at locations requested by McClellan's Environmental Management Office, using funds from a concurrent Cooperative Agreement and from the SMUD charging station budget.

Acceptance of the vehicles did not measurably improve following installation of outdoor charging circuits at the user locations. The low usage throughout the term of the Project was the result of individual preferences of the users. The requirement for helmet usage impacted their acceptance much more than convenient charging availability.

SMUD experiences with City-el vehicles

Sixteen City-els were purchased by SMUD directly from City-Com prior to beginning the DARPA NEV Project scope. SMUD used these vehicles for display, demonstration, and as developmental and parts vehicles for PEV's Project work. Soon after PEV's marketing and lease activities were under way, the SMUD-owned vehicles were set aside for only these purposes and to allow concentration on Project vehicles.

Charging infrastructure convenience was a significant aspect of vehicle acceptance in SMUD's experience also. This was not, however, a critical factor. This was due to the "free usage" to vehicle users, as opposed to lease payment and insurance requirements for the core vehicles of the Project leased by PEV to local customers.

Certain of the SMUD vehicles were provided to PEV to carry out the NEV development (Peregrin) portion of the project, converted to four wheels. The four wheel City-el design work proved the value of such an upgraded design, for market and safety reasons.

The reactions of potential EV purchasers to the four-wheeled City-el was much more positive than to the stock vehicle. The "car" appearance was the dominant factor in acceptance, but this did not satisfy the seating capacity and performance inadequacies.

Battery Experiences

The NEV Project provided a wealth of experience with current battery and charger technologies and their performance and maintenance. Batteries in Project vehicles were nearly all flooded lead acid traction batteries, of the thin plate, 12-volt variety.

Sealed batteries of two manufacturers were installed for trial uses. These included Teledyne and GNB 1180 series batteries. See the battery and charger related reports by PEV in the attached Appendices.

A separate but related effort involved Inductran Corporation, which resulted in a first generation battery electrolyte conditioning system. The system used "cell pumps" to cause mixing of the electrolyte in each cell in each battery module. Certain aspects of the effort were successful, however an overriding material compatibility problem caused SETC to halt use of the system on test vehicles. Inductran has continued development of their concept, at a low level of effort. Compatibility of materials in acid environments was the major failing of the design.

NEV data acquisition
A large volume of data was obtained by PEV during the Project. This data is generally comprised of electronically acquired data and manually logged/recorded data. The Final Report of PEV includes a data summary as an appendix.

The data acquisition systems used for this Project were statistical mode based systems capable of summarization of an entire month's data before downloading. Reveiw of the data system following completion of the Project has determined that energy usage was overstated. The vehicles used by private lease customers are reported by PEV to have used an average of 400 AC wat-hours per mile. The actual usage is less than 300 AC watt-hours per mile. See PEV's Final Report data summary for additional details on data from the Project.

Component Testing
Over the three year span of the Project, a number of component test activities were undertaken, from motors to chargers to glazing material evaluations. Most testing was performed by and for Pacific Electric Vehicles. There were other component level tests performed by others, with the potential usage of all data by PEV the primary objective.

Component testing by PEV was divided into four groups, as follows:

a) Mains-Charger-Batteries

b) Batteries-Controller-Motor

c) Motor Torque to Driving Force Conversion

d) Auxiliary Systems (Batteries, DC-DC Converter, loads)

The testing of these four general groupings of components was outlined in PEV's "Component Test Plan" dated July 26, 1994. Results of specific tests performed are included in various test reports and other documentation completed by PEV and submitted to SMUD November, 1996 or prior.

The Trans2 Alternative NEV
Two NEV prototypes constructed by Trans2 were purchased through this Project. A significant effort was made to thoroughly field test these vehicles, in a number of settings in California and elsewhere. These two vehicles were used by Trans2 to assist in their marketing of their manufacturing plans. Trans2 appears to have been successful in establishing a site for manufacturing in St. Louis, although specific production plans are not known.

The two project vehicles have been in routine use at various times at SMUD facilities for the last year of the Project. They have provided satisfactory service, however there is

limited demand for such off road NEVs. Test use at McClellan did not result in any long term requests for these vehicles. Low performance vehicles have many uses at McClellan, however the Trans2 has little cargo space (3 to 4 ft^3). Figure 1 shows a Trans2 with its removable side curtain doors. The vehicles purchased for this Project did not include side doors.

No significant technical evaluation was performed on the Trans2, as this was not a priority aspect of this Project. The NEV development activity of the Project (Pacific Electric Vehicles) had no association with Trans2, and none was proposed to either company.

See the following section for more general information on our assessment of the market potential for NEVs of two particular uses, generally private community use and low to moderate speed surface street use.

The NEV Market

The NEV market was known to exist prior to beginning the Project. For any closed environment such as a military base, NEVs can satisfy a significant transportation need on base. The market is broad, but not of significant technical importance to DAPRA. The support network for EVs and hybrid EVs may be the same in some regions of the country, but likely will be segmented in most of the urban areas of North America. It also may be concentrated in the sun-belt states for the foreseeable future.

The most serious market entry NEV to date is probably the Bombardier NEV. Although not intended to satisfy even the commuter market, it does have applications at military facilities, and may be under the price threshold for procurement by individual bases, as opposed to the national military vehicle procurement office at Warner-Robbins AFB. It also could have applications for most any closed industrial site or closed community that chose to accommodate such vehicles.

Bombardier is committed to marketing their just introduced NEVfor four to five years before a different product would be introduced. Since this initial NEV is not intended for mainstream commuter use, the opportunity remains for Bombardier or another vehicle manufacturer to develop an NEV that is both capable and legal for use on surface streets by commuters not needing freeway or highway access.

Administrative Activities and Expenditures

The Project spanned greater than three years time, with one primary change of direction for the project occurring in 1994. The primary impact of the change to the Project was a delay in formal approval of the revised work scope and internal authorization within SETC. Coupled with the revised scope of the Project was a slight reduction of the allocation of DARPA funds to the Project.

Expenditures for the Project were generally as planned and approved. A significant increase in matching costs was incurred by PEV throughout the Project. This resulted in a total expenditure by PEV of over $439,000 versus the planned obligation of $256,000 at the time the major restructuring of the Project occurred.

Expenditures by SMUD for the activities for which SMUD was responsible totalled over $277,000 This is slightly less than the original planned figure of $285,000, decreased as a result of restructuring the Project. An additional expenditure by SMUD of $100,000 to Aerojet was not reported as matching costs. This was originally planned for reimbursement through Federal funds not from DARPA, but from the Federal Transit Administration. The reimbursement did not occur, and therefore this expenditure could qualify as a matching contribution. It has not, however, been reported as such.

Overall Project expenditures totalled over $1.5 million, with nearly $600,000 being DARPA funds. Each quarterly/triennial/bienniel DARPA conference was attended by SMUD, and nearly each conference over the term of the Project was attended by a representative of PEV. Due to the extended term for the Project, this involved additional expense to PEV.

Neighborhood Electric Vehicle Market and Product Test and Development Project
Final Report
15 November, 1996

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Pacific Electric Vehicles

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FINAL REPORT:
NEV Market and Product Test and Development Project ("the NEV Project")

1.0 Executive Summary

During the term of this project, market needs for a 35 mph, 35 mile range Neighborhood Electric Vehicle were identified by placing a relatively large number of City-el vehicles for a two year period. The City-el is a three wheeled design with a top speed limited to 33 mph on flat ground. The design and materials of construction preclude raising the speed capability of this platform because of stability concerns. We trained all vehicle users in safe driving of the City-el and conducted a safe program with no accidents. We logged more than 60,000 miles, and collected 15M bytes of data.

The City-el's were fitted with Data Acquisition Systems. and leased to private customers in Sacramento, and to McClellan Air Force Base for use on the base. Over the project, the private customers averaged 222 miles per month, and the on base users averaged 36 miles per month. The range of the City-el appeared to us to be a minor concern of our customers. They seemed to adapt easily.

Reasons for turning the vehicle back in were usually passenger or cargo capacity or lack of freeway capability. Reasons for not leasing initially were usually safety concerns, or lack of four wheels and two seats.

Early in the project it became clear that a vehicle with roughly twice the capabilities of the City-el was required. Better materials needed to be used to increase the perceived and actual safety of the vehicle, and ultimately to meet the crash safety requirements of the FMVSS.

We improved the City-el vehicles by fitting fiber reinforced plastic canopy tops. This reduced the flimsy feel of the vehicles, and helped to keep them in service when the OEM Acrylic Tops failed. We also tested the four wheel need by constructing three four wheeled City-el vehicles. In response to Customer requirements, the top speed was raised on one of these four wheelers. The four wheeled City-els are roughly three times more acceptable to prospective customers than the original three wheeled design.

Finally we designed and constructed a four wheeled NEV prototype we have called the Peregrin. The specification for the Peregrin was designed in response to objections to the City-el provided by our Customers. This specification is provided in Appendix 1. Based on initial testing we expect the Peregrin to meet the performance requirements we established, in spite of being overweight. Top speed

is 45 mph, and range is expected to be 35 miles at 35 miles per hour with conventional lead acid batteries. Charging speed is about 10 miles per hour of charging on a 120 V 20 Amp circuit. AC energy use is expected to be 300 W-h per mile, and DC energy use is about 100-150 W-h per mile.

Suspension, brakes and steering were designed and fabricated especially for the Peregrin. Initial tests show these systems combined with a very stiff body chassis work very well. The Peregrin is designed with a low cost DC drive system rated at almost 20 kW peak. To protect the batteries the current limit is turned down to provide 15.8 kW peak. The drive provides regenerative braking, and adequate acceleration. Cruising at 35 miles per hour requires about 50 Amps.

Through additional market study with the Peregrin, we are looking forward to confirming that we have constructed a prototype NEV which meets the needs of prospective customers. Future work will include manufacturing plans, safety compliance testing, and development of the vehicle systems.

2.0 Scope

This Final Report provides an overview of our activities from the start of the project in August 1993, through it's completion in November, 1996. The project has four sub-parts, namely the NEV Demonstration, The Canopy Improvement Project, the Four-Wheeled City-el prototypes, and the design and construction of an all new, all composite four wheeled two seat NEV, the Peregrin. This final report necessarily references reports written over the term of the project for details of our work. A list of this documentation is provided in Appendix 3.

2.1 Neighborhood Electric Vehicle Definition

We define an NEV as a vehicle which fulfill personal transportation needs around the neighborhood, including around town errands and short trips. The vehicle should have a range of 35 miles at 35 miles per hour. To offer appropriate utility for most people two seats and four wheels are required. The vehicle must be relatively low cost. We learned through this project that for on street use in Sacramento, a top speed of 45 miles per hour was required, otherwise owners will be reluctant to use the vehicle for certain trips.

3.0 The NEV Demonstration

This part of the project required acquisition and deployment of 48 City-el electric vehicles from the manufacturer in Denmark. The acquisition process commenced in August, 1993, and deployment started in December, 1993.

3.1 Data Acquisition

Manual data sheets were taken monthly through out the deployment of the vehicles until September, 1995. A Data Acquisition system was installed in the vehicles, which allowed collecting mode based statistical data reflecting the trips and charging habits of vehicle operators. Over the term of the project private customers drove an average of 222 miles per month, and used 400 AC Watt hours per mile. Customers on the Air Force Base drove an average of 36 miles per month, and used about 2300 AC W-h per mile.

The DAS data was downloaded and provided to SMUD monthly for analysis. We found the DAS capability for recording time series data valuable in performing a number of tests on the City-el vehicle system. These tests were documented and the data furnished to SMUD. In all about 18 Mbytes of data were collected and submitted to SMUD. A summary of data collected is provided in Appendix 2, along with some analysis of the data.

The DAS data shows that users of NEV's typically define trips the vehicle can make, and then repeat these trips with regularity. Individual customers tended to have a need for a single seat vehicle, and didn't need to travel more than 20 miles or so in a single trip. Opportunity charging or charging at work was used when needed to extend the range.

3.2 The Market for Neighborhood Electric Vehicles

A key consideration for our project was to determine the market potential for Neighborhood Electric Vehicles. We set out to determine the needs of potential customers such that product development work could proceed in this direction. Is there a need for a personal transportation vehicle with limited range, speed, and size? If so, what would this product look like? Through the data acquisition efforts we collected data on how the City-el was used. This "use data" helped with development of a product capability specification.

The mechanism for our study was to acquire 48 City-el electric vehicles with ARPA funds, and then to lease these vehicles to customers in the Sacramento Area at a lease price of about half the cost of a normal commercial lease ($120 per month). We also worked out all the details of importation and transportation of the vehicles from Denmark.

Beginning in early 1994 we had the opportunity to become somewhat intimate with our lease customers transportation needs. We also showed the City-el to a large random sample general public. While the City-el was the basis of our study in terms of a product example, and while we had somewhat defined the attributes of an NEV product, i.e.: limited range, small, speed limited we tried to be flexible in

our hearing the voice of the consumer in the personal transportation market. Hopefully this allowed us to be a little more flexible in terms of the definition of an NEV.

Market studies by others, notably the Institute of Transportation Studies, have considered acceptance of other NEV designs. These studies are often broader in their definition of the neighborhood vehicles in terms of capability for speed, but are consistent in defining the intended use of NEV's as "local personal transportation requiring only short range capability of the vehicles".

We focused on the consumer market, and the closed facility market. We wanted to get a feel for what the best market might be for an initial NEV product launch. During our project we therefore interviewed clients at McClellan AFB, and also interviewed the general public in the Sacramento area.

Our primary Market Study effort spanned the beginning of the project in September 1993 through June of 1994 when product design, development and fabrication activities started. Our market findings are summarized in the presentation materials for the Neighborhood Electric Vehicle Workshop on 6/30/94. Some additional comments and details are added in the following.

3.3 Market Study Findings

We cannot report that the City-el met with wide or ready acceptance in the greater Sacramento Area. The City-el is too slow, too small, too flimsy for use by most consumers in a busy city like Sacramento. We were able to lease 25 vehicles to Air Force base users. We also provided a leased vehicle and service to 17 private customers. From January 94 through September 95 average vehicle deployment was 34 and maximum vehicle deployment was 39 units.

At McClellan Air Force base the average daily use of the vehicles was only 1.2 miles per day or 36 miles per month. A vehicle with less range capability than a City-el would have sufficed. We have no data on the average fleet mileage per day, but we believe from interviews that *the average daily use would have been higher if the City-el could have carried cargo and two people.*

It was relatively easy to record the objections to the City-el, since they were many. Overall the City-el was mainly judged not to offer enough utility or comfort for most people interviewed. We leased the vehicle mainly to people who could visualize specific trips they would enjoy making with a small, quiet, electric vehicle.

We can also say that we might have leased the vehicle for less money, but we rarely had price raised as an objection unless connected with if it "offered more utility or carried two people" it might be worth that. Safety was also questioned frequently.

It is important to note that everyone who drove a City-el received a safety briefing including a warning not to roll the vehicle. The safety briefing is described in our submittal of 5 April, 1994. More than 100 employees at McClellan AFB were trained in safe use of the City-el, and our training program was approved by personnel responsible for safety on base.

The main problems with the City-el were the three wheeled design, low speed, and lack of two seats. The three wheeled design necessitated the safety briefing, and although compromising pure market results by increasing safety concerns, we had a safe project with no accidents. It is hard to sell a product when you essentially have to explain it's deficiencies prior to offering a test experience.

The top speed of an un-modified City-el on flat ground with specified tire pressures is 33 miles per hour. Based on our study we believe the minimum acceptable top speed for a consumer market NEV is 45 miles per hour. Freeway speed capability is highly desirable and significantly increases market size. In our view this is probably acceptable even with the range reduction to less than 20 miles. The top speed of the vehicle was perceived as a significantly bigger problem than its 20 mile range.

The need for two seats was mentioned mostly by people who were prospective customers. The lack of two seats limits the utility of the vehicle, decreasing its desirability. Many people interviewed asked "where does my better half sit". Since EV's will initially be targeted to early technology adopters, it's reasonable to expect that the owners will want to show off a little by giving friends a ride.

3.3.1 Attributes of The City-el

The City-el is very quiet. Quiet is often mentioned as a reason to enjoy driving the vehicle. The City-el is very easy to park, has adequate range, and is unique. The controls and instrumentation were judged to be good. The charger and capacity gage functioned fairly reliably throughout the project, and we had few people stranded by surprise. Over time the City-el seemed to become a very personal transportation product, as it became part of the owner's daily routine. Driving a City-el is almost always something done by oneself. The City-el is easy to use, fun to drive, and all customers could identify specific uses for which the City -el was suited. These uses tended to continue throughout their possession of the vehicle. Daily mileage increased seasonally, and users reported lack of visibility in bad weather as a problem.

If the transportation needs of our customers changed so the City-el no longer worked for them. the vehicle was returned to us and replaced with a car which provided suitable utility (capacity, speed, range). We had several lease customers change jobs or circumstances and regretfully return their vehicle. We had only one customer who misjudged his needs, who found the City-el unsuitable soon after leasing it. This customer returned the vehicle after four months. His routine required a lot of hill climbing, and frequent trips on unpaved roads.

The range of the City-el has been acceptable for all our customers. All customers were informed the range of the City-el in flat country is 20-30 miles depending on how you drive. This was accepted by the customers, and no customer has complained of the range. Several customers took advantage of opportunity charging to drive 50 to 60 miles per day.

Increased range increases the value of the vehicle, because it increases the possibilities for usefulness. Data collected with the data acquisition system shows that our lease customers identified specific trips they could make, and then repeated them with regularity. If a prospective customer could not visualize appropriate trips with the City-el, they remained a prospective customer.

3.3.2 City-el Problems:

Safety Concerns: the vehicle simply doesn't appear to offer sufficient safety. the original canopies gave them a flimsy feel, and "three wheels, is that stable?" "I'll bet you are road kill if you are hit in that thing." It is too small and hard to see. In addition:

- The City-el is hard to see out of.
- Short people in particular have to look through the steering wheel.
- Seats are not comfortable, it is a good thing the vehicle has a short range.
- Defroster not adequate
- Water drips from the canopy when it is raining.
- The vehicles were fitted with vinyl convertible tops and while lockable, offered no security for the contents of the vehicle. We had few troubles with vandalism however.
- Helmets were required of drivers
- Hard to get in and out of.
- Rough Riding
- Too much like a bicycle in the lane for cars.

We concluded that a somewhat larger vehicle with four wheels, two seats, and a little higher top speed was required. A more acceptable NEV must remain

inexpensive ($10,000 per unit or less in reasonable manufacturing quantity), must have two seats, four wheels, have a useful range of at least 30 miles at 35 miles per hour, and be safe for the occupants in an accident. It should have good visibility out, and look strong and useful from the outside. It should have cargo capacity of at least 200 lbs with two passengers.

3.3.3 City-el reliability

We were able to keep all of leased vehicles running through-out the project. Most problems were relatively minor and were repaired within a week of their occurrence. There were a number of recurring component problems which were discovered early on. These are described our report "Analysis of Monthly Data" dated April 19, 1994 (four months after starting to lease vehicles). One of the most troublesome problems was the early failures of canopy tops. One early failure was due to user attempting to crawl over the top to enter the vehicle and low strength material of construction. The others were due to the thermal expansion of the thermoplastic material. This thermal cycling caused cracking in about 1/3 of the canopies replaced later in the project with fiber reinforced plastic canopies made by PEV later in the project, please see paragraph 5.0.

4.0 First Steps, the four wheeled City-els

As a first effort to address the stated needs of customers we constructed three four wheeled vehicles on the City-el chassis. We called the vehicles the "Persport". These vehicles when finished were fun to drive as the cornering capability was substantially increased without much weight penalty. The 690 lb curb weight of these vehicles was only 30 lbs greater than the original City-el. We began designing these unique conversions in June 94, and completed testing in June 95.

Based on comments from people interviewed when these vehicles were shown, we believe the four wheelers were viewed as substantially a more attractive and acceptable vehicle because of it's wider stance and four wheeled design. We had thought the four wheeled design would have higher rolling resistance than three wheels, however the difference was found to be small.

Our purpose in constructing the four wheeled vehicles was to test attachment of suspension to composite, and to get some on road experience with very light four wheeled vehicles. The first two four wheelers retained the original upper steering linkage which is raised with the canopy top. They also retained the original rear suspension and drive. Testing of these vehicles was documented in our report titled, "Persport vs. City-el Test Report" (6/29/95).

While the cornering capability of the vehicle had been increased, we can report that the rear suspension still provided a harsh ride because of a high unsprung weight on

the rear axle. The torsional stiffness of the thermoplastic over polyurethane foam chassis was not adequate to fully take advantage of the capabilities of the suspension, and the speed was still inadequate. The first two vehicles also suffer from excessive bump steer, and too low a steering ratio.

The third four wheeled vehicle included a revised rear suspension, a 60 volt drive, revised steering geometry, and modifications to decrease the weight of the vehicle and increase the battery mass fraction. This vehicle was never fitted with a data acquisition system, and minimal quantitative data was collected. It is still available for testing. We also tested additional ideas for attachment of suspension to composites, and developed fabrication processes for the NEV prototype Peregrin during the construction of this vehicle. Testing of the third four wheeler is documented in "Testing Notes, Persport #3" (11/1/96).

The 60 V four wheeler is capable of 40 miles per hour on flat ground, and is more comfortable in traffic than a City-el. The first two four wheelers with a City-el drive could be the basis of an on base utility vehicle by addition of a seat and a small cargo bed. The speed and range capabilities of these vehicles was entirely adequate for on base use.

5.0 Canopy Top Improvement

The City-els were delivered from Denmark with an Acrylic (PMMA) canopy top which was thermoformed in clear material, reinforced with a fiberglass tube filled with polyurethane material. A steel tube down the center of the urethane material presumably was intended to provide additional strength. The top part of the vehicle is reinforced in the front with an aluminum tube weldment which supports the dash and the steering, and provides a hinge point relative to the bottom chassis part. The Canopies are painted selectively for finish.

In service the top changed shape, bowing up along its length sometimes as much as an inch as a result of it's construction. This temperature induced deflection caused fatigue cycling of the acrylic, and many of the tops eventually cracked. The thermal ratchet cycling of the top also made it hard to keep the latch mechanism adjusted so the canopies would latch down, especially in the fall and the spring.

We set out to design, tool and produce fiber-reinforced canopy top to replace the original canopies. At first we considered having a canopy thermoformed in better clear glazing material, and concluded the tooling cost quoted by suppliers with this capability was too high to be justified with the number of canopies we believed we would likely need to produce or find a market for, even though there were at the time an estimated 2500-3000 City-el's in service in Europe. We hoped that designing and building our own canopies using fiber reinforced plastic (FRP)

would facilitate process development for NEV body parts and would help us gain experience in working with plastic glazing material. These goals were realized.

The canopy improvement project bean in July 1994, and as of now 55 canopies have been produced. With the exception of one 10 lb Carbon fiber canopy top, all of the canopies were molded with E-glass and high impact strength polyester resin. Weight is 30 lbs, which is equivalent to the original canopies. The process is described in our submittal titled "Process Description: City-el Canopy Fabrication" (4/19/95). After making three prototypes from a very light weight mold, a new plug was finished and a heavier set of four molds was made.

To simplify construction, the new molds eliminated an FRP rag top support "targa top" present on the first improved canopy tops . The new mold also provided a much better finish out of the mold, allowing us to install white gel coat canopies directly on the white vehicles without refinishing. Red and yellow canopies were painted.

Uncoated lexan used for the quarter windows and tested on the first prototype. It was immediately clear that un-coated, lexan does not offer sufficient scratch resistance for vehicle use. All of the canopies after that utilized Lexan MR5, which is coated for abrasion and UV resistance. This material could be laser cut economically, and because the front quarter windows are relatively flat, were cold fitted to the shape of the top. This glazing material is much tougher than the original acrylic, and has held up well over the life of our project, retaining its transparency.

The construction of the improved canopies is a bonded hollow tubular structure which attaches to the original mounting points on the aluminum top part support. This has greatly reduced the flimsy feeling of the vehicle, and the new tops reliably close with a satisfying solid latching. The original laminated safety glass windshield is retained. We have installed 54 canopies on the vehicles in Sacramento.

6.0 NEV Prototype

We have completed construction of a prototype NEV we call the Peregrin. We believe the Peregrin satisfies many of the requirements customers and potential customers for the City-el's expressed to us. The Peregrin is a small yet substantial vehicle design. The interior space is as small as we could make it and still fit two 95% males. The windshield is far forward to maximize run-down length for the passengers and to provide a spacious feeling. The windshield is rather vertical to provide good visibility from a relative small piece of laminated safety glass.

The Peregrin prototype is intended to provide a basis for designing a manufacturing system to produce NEV's for sale in the $10,000 or less price range. The prototype will also be used for ongoing exploration and testing of the NEV market.

The Peregrin is designed around a 72 Volt drive with a regenerative braking motor controller and a series wound motor. This drive was chosen because a more expensive drive was judged unsuitable given our production cost goals. The batteries in the Peregrin are intended to be replaced at a price of around $600, minimizing cost to customers. The battery mass fraction goal was 40% with 400 lbs of batteries. The 1190 lb Peregrin Prototype has a battery mass fraction of is 33%, as it is about 200 lbs over weight. Most of the weight excess is in the body chassis, which was made a little heavy for the first unit because of the processes used.

Design of the Peregrin prototype commenced in June 1994, and the prototype was completed in November, 1996. This works out to 29 months from a clean sheet of paper to a running prototype. Based on our initial tests of the vehicle we believe we have met most of our technical goals, with the exception of slightly reduced cargo capacity because of the weight, and higher AC energy use (about 300 W-h per mile) since flooded batteries are being used for initial tests. Testing of the prototype is still in process to confirm the specification provided in Appendix 1. Some additional notes on the design process, design features and goals, fabrication and assembly follow.

6.1 Design

The need for a strong vehicle with a substantial structure was clear from our City-el experience. We wanted to design a low mass suit of armor. If a vehicle is to be light enough to achieve the performance goals derived from the City-el project, and still be capable of being produced for $5000 factory cost, it was obvious that it had to be small. These factors combined with our experience with the environmental response of thermoplastic used in the City-el lead us to conclude that fiber reinforced plastic was needed.

The need for material strength and toughness was confirmed through engineering stress and deflection analysis of the proposed vehicle shell design. We set out to design the structure to be able to withstand the impact loads of the crash testing requirements in FMVSS 208 and 214, and the roof crush requirements of FMVSS 216. Our design analysis is summarized in our report titled Peregrin Body-Chassis Design, submitted June 8, 1995. The prototype was constructed according to the criteria described in that report. E-glass with Epoxy matrix was used, with aramid honeycomb, and other cores.

The design also included a complete front and rear suspension system. The front is based on un-equal length A-arms, and the rear on trailing and lateral links. Both front and rear use coil over shock absorbers with adjustable ride height. Four piston brake calipers from a Suzuki 600 Katana were adapted to the system, with special cast iron rotors. Wheels are 3x15, and 115-70R-15 radial tires are used. Initial tests suggest that our suspension system achieves a good balance in ride and handling, and that the unsprung weight of the systems is appropriate to the overall vehicle mass.

We developed a compliance plan for the Peregrin, which provides an initial compliance strategy for all requirements of the Federal Motor Vehicle Safety Standards. This strategy is provided in our submittal of 8 June 1995, titled "Safety Characteristics, Peregrin Neighborhood EV." By November, 95, most design details for the suspension, brakes, steering, lighting, glazing, and drive was complete. These are all covered by submittals and documentation, please see our Research Document List, Appendix 3.

6.2 Construction:
Following completion of the overall vehicle layout, tooling to produce the shell was well underway by July 95, and completed by the end of September, 1995. A nine piece mold was constructed. This mold can be bolted together to form the entire vehicle shell minus the flat floor. Fairly heavy 8mm thick molds were fabricated using matt, woven fabric, and isophthalic polyester resin.

Construction of the body-chassis shell was undertaken immediately following mold completion. On January 11, 1996 the body shell was demolded. The weight of the hollow shell was 150 lbs, about 40 lbs over weight. This was attributed to the layup method. To achieve a good surface, we had applied two layers of fabric to the mold surface by wet lay-up, and allowed this to cure. This was intended to prevent the core material from bunching the surface layup as the cores were pulled into contours in the mold. Following cure of the skin layer, a three layer laminate was made, the core seated on this by vacuum bagging. A final inner layup was then vacuum bagged onto the core. We intend to experiment later with other techniques which would allow a shell built to the weight budget.

Internal structures were fabricated and bonded into the shell. Note that no tools were made for the interior structures, rather they were fabricated using aircraft flooring and cut and fold method. These were bonded in and then reinforced with wet layup. This method is also heavier than construction with a mold and vacuum bagging or compression molding.

Suspension, steering, brakes, and drive components were fabricated in parallel with the composite structure. In March 96 the front and rear suspension were prefit to their attachments, and the clearances for the fender wells were verified. A short lapse in the work because of resource constraints occurred in April and May 1996. The body shell was essentially complete by this time, and a little body work was done. In June work resumed in earnest and the body shell was painted on August 26, 1996.

We made tools to allow fabrication of a dash board, seats, and for forming the glazing. Seats weigh 2 kg each, and are carbon fiber, E-glass and epoxy over balsa and pvc cores.

During September and October 1996, final assembly and wiring of the vehicle were completed. We drove the vehicle for the first time on November 11, 1996 following a thorough check out of both 72 volt and 12 volt systems. Lights, windshield wipers, defroster, and all controls and instrumentation are functional. The DC-DC converter was checked at it's maximum output, and test data recorded.

Initial Testing:
We have only performed the briefest tests in driving the vehicle. Our initial impressions are good. There is a little excess noise being transferred by the drive to the chassis, and experiments will have to be done to define reduce this. Acceleration and speed meet expectations, and 45 mph has been reached. There is a reasonable amount of acceleration to be felt at 25 miles per hour, and Peregrin is comfortable to drive in 45 mph traffic. Cornering capability and the feel of the steering are good.

The regenerative braking current is set too low, and this will have to be adjusted. Maximum drive current used to date is 215 Amps, however the system is capable of more and we will drive it harder once the batteries are cycled some more and things are broken in a little. The brakes, suspension, and steering feel very good. Turning radius seems acceptable. The hand brake works, however we haven't tested the holding power on grades. The Zivan charger appears to work well, however too few cycles to really judge. The charge algorithm is acceptable, and the charger appears to be correctly set.

Future Work:
We have a lot of testing ahead of us to measure the vehicle system. We are looking forward to a 6 month development and study process in which the vehicle is measured, and manufacture options are reviewed. Significant work should be done on estimating the costs of more sophisticated manufacturing methods suitable

for modest volume production. Some of this work is being done by Hexcel/ Ciba who are a member in the Sacramento Electric Transportation Consortia.

Safety Compliance verification will require an additional test vehicle, as we don't so far want to crash #1. Some of the other specifications and FMVSS requirements can be checked by our testing of Peregrin #1, even though final verification should be done by a third party.

Appendix 1 Peregrin rendering and specification

Neighborhood Electric Vehicle Market and Product Test and Development Project
Final Report
15 November, 1996

PACIFIC ELECTRIC VEHICLES

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8500 WEYAND AVENUE
SACRAMENTO, CA 95828
FAX: 916-381-2189
PHONE: 916-381-3509

RESEARCH & DEVELOPMENT
190 FORD ROAD, SUITE 111
UKIAH, CA 95482

LOS ANGELES SALES OFFICE
1613 CHELSEA ROAD, SUITE 244
SAN MARINO, CA 91108
FAX: 818-289-5946

Peregrin

a prototype by Pacific Electric Vehicles

Two passenger, four wheeled Neighborhood Electric Vehicle

Range: 30-40 miles (lead acid batteries)

Top Speed: 45 mph

Acceleration: 0-35 mph in 10 seconds

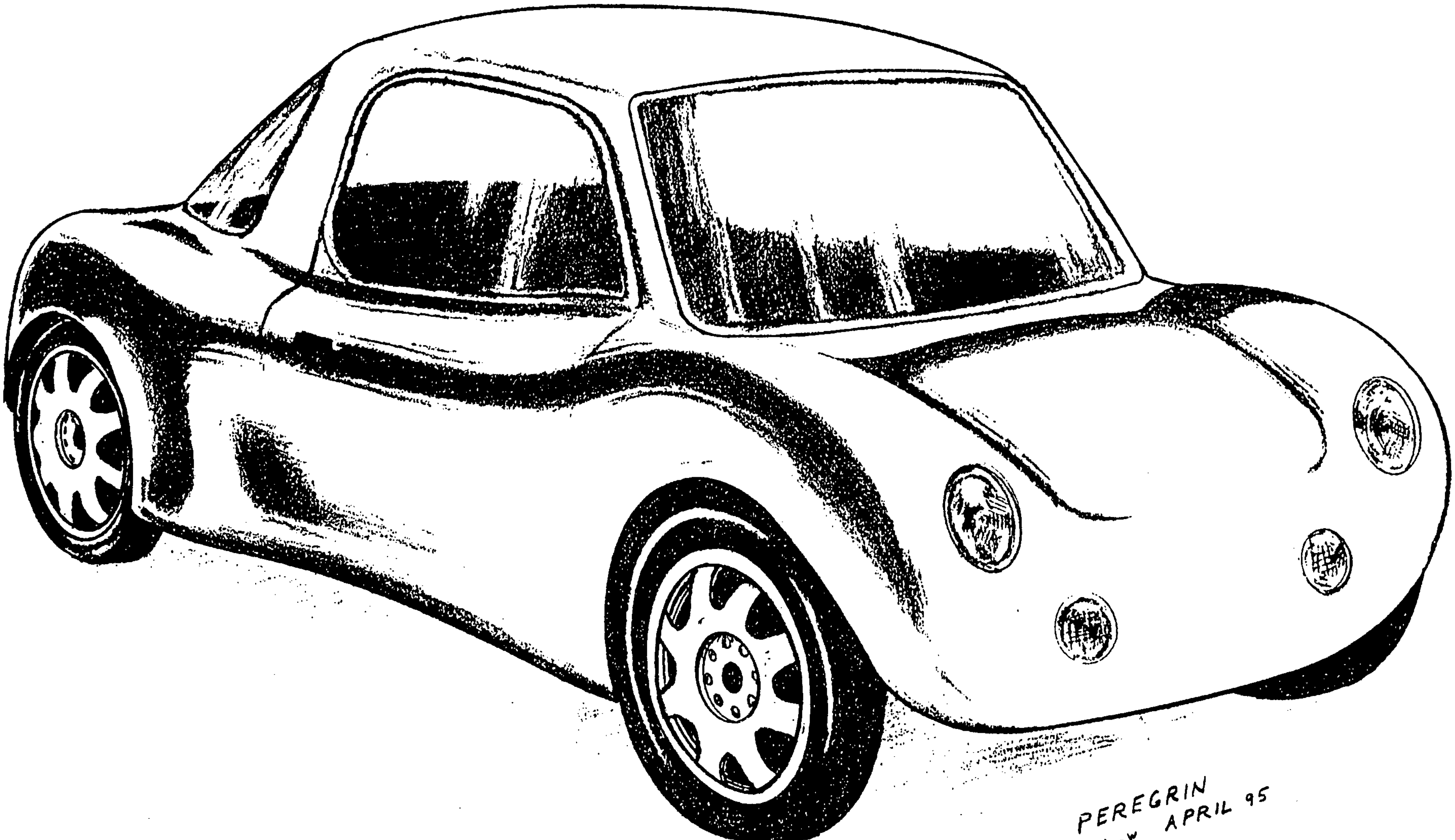
Drive: 6 kW nominal, 15 kW peak...Brush DC Motor and Controller with regenerative braking. Direct drive through a differential with 5.6: 1 total reduction. Maximum Grade 22% with 100 kg load.

Energy use: <100 DC, <200 AC W-h/mile (about 2 cents per mile)

Curb Weight: 450 kg
GAVWR: 700 kg
Battery Mass: 180 -200 kg

Battery Replacement Cost: $600 (lead acid batteries)

Construction: Composite Unibody with rigid passenger enclosure and crushable structures
Wheel Base: 2.2 m (86.63 inches)
Track F/R: 1.3 m / 1.2 m (51.19" / 47.25")
Height: 1.22 m (48 inches)
Overall Length: 3.025 m (199.2")
Width: 1.495 m (58.87")
Cargo Capacity: 8 cubic feet (.226 m^3), 220 lbs (100 kg) with 2 passengers
Brakes: Hydraulic Discs at each wheel
Designed to meet applicable Federal Safety Standards 6/8/95


PEREGRIN
CLW APRIL 95

Appendix 2 Data Acquitsion Summary

Neighborhood Electric Vehicle Market and Product Test and Development Project
Final Report
15 November, 1996

City-el Data Summary

Manual Data

Frequency: Monthly.
Data Taken: See attached data sheet.
Time Span: December 93 to September 95. (Some data from Oct. 95 to Present.)
Data Analysis: Sent Monthly. See attached example for September 95.
Major Changes: Data sheet formatting change in August 94.
Addition of DAS Analysis Guide to Data Analysis on January 95.

Copies:
ARPA File — Original data sheets filed by VIN and Date.
Working Copy — One copy of data sheets sorted by VIN and by Date. Monthly Data analysis filed by type and date. Also three 3.5" Disks of Electronic copies of monthly data analysis sheets. The electronic copies includes a source spreadsheet which contains just raw data from December 93 to September 95 This copy is the most complete and includes a few corrections to data which came to light after the monthly copies were sent.
Bill Warf's Copy — One copy of data sheets and analysis sent monthly to Bill Warf.
SMUD's Copy — One copy of data sheets and analysis sent monthly to SMUD.

Missing Data:

All missing data was not submitted by either the customer or the firm in charge of taking the data. In some cases, the vehicles were not used, and in others, circumstances prevented data collection. 39 Sheets are missing from occasional individual vehicles, and all 25 McClellan sheets for January 95 are missing. The Current total of about 780 data sheets means that about 8% of the data is missing.

Data Acquisition System Data

Frequency: Monthly.
Data Taken: See City-el Data Acquisition System User's Manual.
Time Span: January 94 to September 95. (Some data from Oct. 95 to Present.)
Data Analysis: None, other than as part of special reports.
Major Changes: Prototype systems from January 94 to September 94
Final system in all Vehicles from January 95 to September 95

Copies:
Master Copy — (20) 3.5" disks of uncompressed data files.
Archive Copy — (13) 3.5" disks of ZIP compressed data files for each month.
Working Copy — Approx. 18 Meg of data files sorted into directories by VIN. Each directory contains a text file which lists each data file and special notes on the file or the vehicle. This data is available on a QIC-80 format 2120 tape.
SMUD Copy — Identical to the Master Copy and sent monthly with the manual data.

Missing Data:

The exact amount of missing data is unknown. Some vehicles are missing the monthly download file, and some vehicles have corrupted or mis-downloaded files.

City-el Inspection Report **Neighborhood Electric Vehicle Program**

VIN = ____________________
Date = ____________________
Inspection by = ____________________

Start DAS download procedure: __________
Kilo-Watt hour meter reading = ____________________
Odometer Reading = ____________________

Tires / Wheels	Pressure (as Found)	Tire Wear	Wheel Condition
Front:	(35 psi)__________	__________	______________
Left Rear:	(37-40)__________	__________	______________
Right Rear:	(37-40)__________	__________	______________

Jack up front of vehicle and check play in front wheel: ______________________
Clean and Lubricate Clutch Disc: ____________________

Batteries (if batteries appear nearly full check specific gravity.)

Water Added (in Liters): __________ Left Battery: ________________
Battery Appearance: ______________ Center Battery: ______________
Battery Type: ___________________ Right Battery: _______________

Complete DAS Download: __________

Diagnosis Box

Voltage: __________ State of Charge %: 82% 100%
Dots: _____________ 12 Volt Light: Yes No ETG Light: Yes No

Chassis Checks

Body Condition: ____
Lights Operation: ____
Brake Fluid Level: ______________ Window Washer Fluid Level: ___________
Plug in Charger and Verify Function: ______________________________
Drive Vehicle: ____

NOTES:

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

Monthly Data Analysis for City-El

Print Date: 9-29-95

Month of: Sep. 95

Vehicle Identification Number	ID #	User	Data Date	Watt hrs	Odometer	RAW DATA Specific G	H2O	Dots	%last chg	Lights
UH5MSE04XPRS03990	3990	McClellan	9-27-95	918653	755.1	1.3	0.35	12	100	none
UH5MSE041PRS03991	3991	McClellan	9-26-95	607810	966.1	1.275	1	10	100	none
UH5MSE043PRS03992	3992	McClellan(I)	8-21-95	591257	1202.4	No Data for this month.				
UH5MSE045PRS03993	3993	Teledyne	6-23-95	1081197	2507.6	No Data for this month.				
UH5MSE047PRS03994	3994	Childers	9-25-95	1322260	3525	1	2	11	?	none
UH5MSE049PRS03995	3995	McClellan	9-27-95	338437	640.6	1.27	0.39	12	82	etg
UH5MSE040PRS03996	3996	McClellan	9-27-95	876063	600.2	1.3	1.2	12	100	none
UH5MSE042PRS03997	3997	McClellan(I)	8-21-95	413392	347.4	No Data for this month.				
UH5MSE044PRS03998	3998	McClellan	9-26-95	938720	358.6	1.3	0.28	12	100	none
UH5MSE046PRS03999	3999	McClellan	9-26-95	25089.2	490.9	1.225	0.51	12		none
UH5MSE047PRS04000	4000	McClellan	9-26-95	854806	1099.3	1.25	0.61	12		none
UH5MSE049PRS04029	4029	McClellan	9-27-95	810013	584.7	1.275	0.26	12	100	none
UH5MSE046PRS04030	4030	Ukiah	6-17-95	316532	4880.1	Out of Service				
UH5MSE047PRS04031	4031	Ukiah	2-18-95	965572	2199.9	Out of Service				
UH5MSE049PRS04032	4032	Whitney	9-12-95	?	4999.6	?	0.75	9	82	etg
UH5MSE040PRS04033	4033	pev	11-14-94	108972	49.2	Out of Service				
UH5MSE045PRS04125	4125	McClellan	9-27-95	412673	346.9	1.3	1	12	100	none
UH5MSE047PRS04126	4126	Ukiah	6-15-95	838817	1597.1	Out of Service				
UH5MSE049PRS04127	4127	McLoudry	9-11-95	884214	1456.8	?	1.7	12		none
UH5MSE040PRS04128	4128	Warf, Ukiah	8-17-95	588315	751.3	Out of Service				
UH5MSE042PRS04129	4129	Townsend	8-29-95	987015	2736.6	No Data for this month.				
UH5MSE049PRS04130	4130	McClellan	9-27-95	871976	380.4	1.28	0.18	11	100	none
UH5MSE040PRS04131	4131	McClellan	9-27-95	804674	1022.8	1.225	0.38	9	100	none
UH5MSE042PRS04132	4132	McClellan	8-29-95	1000118	987.8	Broken Drive				
UH5MSE044PRS04133	4133	McClellan	9-27-95	747153	972.4	1.3	1	12	100	none
UH5MSE046PRS04134	4134	McClellan	9-27-95	635999	364.9	1.225	0.15	8		etg
UH5MSE048PRS04135	4135	PEV use	1-24-95	435327	677.4	Out of Service				
UH5MSE04XPRS04136	4136	pev	1-24-95	163168	131.4	Out of Service				
UH5MHE043PRS04137	4137	pev	11-14-94	45545	82.6	Out of Service				
UH5MHE045PRS04138	4138	Warf, Ukiah								
UH5MHE047PRS04139	4139	McClellan	9-26-95	1098345	1913.6	N/A	N/A	12	100	none
UH5MHE043PRS04140	4140	pev	10-31-94	45635	92.5	Out of Service				
UH5MSE043PRS04141	4141	pev	7-20-94	9230	21.1	Out of Service				
UH5MSE045PRS04142	4142	McClellan	9-26-95	443226	478.7	N/A	N/A	12	100	none
UH5MSE047PRS04143	4143	Ukiah	6-15-95	507306	272.7	Out of Service				
UH5MSE049PRS04144	4144	Baer	9-7-95	?	?	?	0.75	?	100	none
UH5MSE040PRS04145	4145	pev								
UH5MSE042PRS04146	4146	Twombley	9-12-95	203362	329.2	N/A	N/A	10		etg
UH5MSE044PRS04147	4147	Cartwright	8-25-95	1521031	5068.5	No Data for this month.				
UH5MSE046PRS04148	4148	McClellan	9-27-95	898917	960.3	1.3	0.8	12	100	none
UH5MSE048PRS04149	4149	McClellan	9-27-95	990872	628.2	1.26	1.55	9	82	etg
UH5MSE044PRS04150	4150	McClellan	9-27-95	8680721	517.6	1.3	0.56	12	100	none
UH5MSE046PRS04151	4151	McClellan	9-27-95	791320	585.2	1.3	0.33	12	100	none
UH5MSE048PRS04152	4152	Warf, Ukiah	8-17-95	N/A	290.6	No Data for this month.				
UH5MSE04XPRS04153	4153	McClellan	9-26-95	1941234	2570.8	N/A	N/A	12	100	none
UH5MSE041PRS04154	4154	McClellan	9-26-95	830273	966.4	1.3	0.41	12	100	none
UH5MSE043PRS04155	4155	McClellan	9-28-95	332770	1973.8	1.125	0.39	8	100	none
UH5MSE045PRS04156	4156	pev								

4 Wheel Persports

S03344	3344	McClellan	6-15-95	166127	1056.3	Out of Service
S03574	3574	McClellan	6-15-95	200867	799.7	No Data for this month.

This document includes manual data collection for the City-El electric vehicle as specifed in SMUD Participation Agreement F-102 and as part of ARPA grant MDA972-93-1-0025

Monthly Data Analysis for City-El

Print Date: 9-29-95

Sep. 95

ID #	User	SINCE LAST MONTH Days	W*h	Miles	Miles/day	W*h/Mile	TO DATE TOTALS Days	W*h	Miles	Miles/day	W*h/Mile	Mo.	Tot.
3990	McClellan	28		8.7	0.3		651	826785	708.5	1.1	1167.0	1	1
3991	McClellan	28	40900.5	96.1	3.4	425.6	650	547026	921	1.4	593.9	1	1
3992	McClellan(I)						614	532129	1181	1.9	450.6		1
3993	Teledyne						584	973071	2502.2	4.3	388.9		1
3994	Childers	36	99526.5	325.7	9.0	305.6	572	1165245	3468.8	6.1	335.9	1	1
3995	McClellan	28	28095.3	7.5	0.3	3746.0	651	639771	625.6	1.0	1022.7	1	1
3996	McClellan	29	54592.2	76.8	2.6	710.8	651	788455	567.7	0.9	1388.9	1	1
3997	McClellan(I)						614	372051	339.5	0.6	1095.9		1
3998	McClellan	28	44474.4	0	0.0		663	813136	304.9	0.5	2666.9	1	1
3999	McClellan	28	17837.2	18.1	0.6	985.5	650	515542	455.6	0.7	1131.6	1	1
4000	McClellan	28	28905.3	28.8	1.0	1003.7	650	769323	1032.9	1.6	744.8	1	1
4029	McClellan	29	31726.8	2.7	0.1	11750.7	651	729010	559.6	0.9	1302.7	1	1
4030	Ukiah						562	1674282	4874.1	8.7	343.5		1
4031	Ukiah						455	863347	2194.4	4.8	393.4		1
4032	Whitney	32		286.3	8.9		661		4992.2	7.6		1	1
4033	pev						334	98073	25.6	0.1	3831.0		1
4125	McClellan	28	39854.7	19.3	0.7	2065.0	677	593198	342.3	0.5	1733.0	1	1
4126	Ukiah						492	754934	1590.8	3.2	474.6		1
4127	McLoudry	31	43492.5	66	2.1	659.0	914	791408	1450.8	1.6	545.5	1	1
4128	Warf, Ukiah						472	486949	744.9	1.6	653.7		1
4129	Townsend						647	888312	2729	4.2	325.5		1
4130	McClellan	28	32239.8	20.7	0.7	1557.5	677	784777	374.2	0.6	2097.2	1	1
4131	McClellan	27	35991	39.6	1.5	908.9	664	1038788	1017.9	1.5	1020.5	1	1
4132	McClellan						648	900104	983.1	1.5	915.6		1
4133	McClellan	28	63478.8	171.8	6.1	369.5	677	672436	966	1.4	696.1	1	1
4134	McClellan	28	34704.9	5.4	0.2	6426.8	677	572397	357.8	0.5	1599.8	1	1
4135	PEV use						433	391791	668	1.5	586.5		1
4136	pev						432	146849	125.5	0.3	1170.1		1
4137	pev						333	106961	61.3	0.2	1744.9		1
4138	Warf, Ukiah												
4139	McClellan	27	47055.6	106.5	3.9	441.8	676	988507	1907.5	2.8	518.2	1	1
4140	pev						319	41068.8	1.4	0.0	29334.9		1
4141	pev						7	8305.2	17.3	2.5	480.1		1
4142	McClellan	27	32413.5	17.7	0.7	1831.3	447	398902	473.6	1.1	842.3	1	1
4143	Ukiah						258	234775	265.3	1.0	884.9		1
4144	Baer	27					443					1	1
4145	pev												
4146	Twombley	23	19749.6	51.7	2.2	382.0	449	183024	322.2	0.7	568.0	1	1
4147	Cartwright						450	1368926	5061.1	11.2	270.5		1
4148	McClellan	27	44853.3	68.8	2.5	651.9	664	809023	952.7	1.4	849.2	1	1
4149	McClellan	28	54171.9	35.8	1.3	1513.2	664	891784	622.5	0.9	1432.6	1	1
4150	McClellan	28	7071507	12.3	0.4	574919.3	664	7812647	512.3	0.8	15250.1	1	1
4151	McClellan	29	27593.1	1.7	0.1	16231.2	664	712186	579.2	0.9	1229.6	1	1
4152	Warf, Ukiah												1
4153	McClellan	28	47094.3	70.1	2.5	671.8	663	1747109	2563.8	3.9	681.5	1	1
4154	McClellan	28	42730.2	41.8	1.5	1022.3	663	747244	959.4	1.4	778.9	1	1
4155	McClellan	28	8267.4	7.2	0.3	1148.2	665	1028702	1966.8	3.0	523.0	1	1
4156	pev												
		Totals:	7991256	1587.1				3.6E+07	52370.3			27	45
		Average:	295972	58.8	2.0	23323.2		809074	1163.8	2.0	1868.1		
		Std. Dev:	1.4E+6	81.1	2.5	116799.3		1.2E+6	1299.3	2.4	4837.7		
3344	McClellan						177	78261	295.6	1.7	264.8		1
3574	McClellan						140	180761	214.8	1.5	841.5		1

Totals and Averages are not entirely correct due to holes in data.

Hydria Watt-hour Correction Factor = 0.9

This correction factor corrects the Watt-hour reading of the Hydria KWH meter. The Hydria meter reads 10% too high.

Monthly Data Analysis for City-El

Print Date: 9-29-95

Sep. 95

ID #	User	DATA ACQUISITION SYSTEM, ANALYSIS GUIDE Batteries	Charger	Special
3990	McClellan	Trojan 30XH	City-el Standard	
3991	McClellan	Trojan 30XH	City-el Standard	
3992	McClellan(l)	Trojan 30XH	City-el Standard	
3993	Teledyne	Teledyne Sealed	City-el Teledyne	Reversed main shunt wires.
3994	Childers	Trojan 30XH	City-el Standard	Compund, speedkit, and series switching on motor. Hot wired gage.
3995	McClellan	Trojan 30XH	City-el Standard	
3996	McClellan	Trojan 30XH	City-el Standard	
3997	McClellan(l)	Trojan 30XH	City-el Standard	
3998	McClellan	Trojan 30XH	City-el Standard	
3999	McClellan	Trojan 30XH	Pepco Turbo-Z	No Capacity Gage. Hot wired gage.
4000	McClellan	Trojan 30XH	City-el Standard	
4029	McClellan	Trojan 30XH	City-el Standard	
4030	Ukiah	Trojan 30XH	City-el Standard	Reversed main shunt wires.
4031	Ukiah	Trojan 30XH	City-el Standard	
4032	Whitney	Trojan SCS 225	City-el Standard	Hot wired capacity gage.
4033	pev	Trojan 30XH	City-el Standard	
4125	McClellan	Trojan 30XH	City-el Standard	
4126	Ukiah	Trojan SCS 225	City-el Standard	
4127	McLoudry	Trojan 30XH	City-el Standard	
4128	Warf, Ukiah	Trojan 30XH	City-el Standard	
4129	Townsend	Trojan 30XH	City-el Standard	Increased current limit. Compund, speed kit. series switching. Hot wired gage.
4130	McClellan	Trojan 30XH	City-el Standard	
4131	McClellan	Trojan 30XH	City-el Standard	
4132	McClellan	Trojan 30XH	City-el Standard	
4133	McClellan	Trojan 30XH	City-el Standard	Hot wired capacity gage.
4134	McClellan	Trojan 30XH	City-el Standard	Hot wired capacity gage.
4135	PEV use	Trojan 30XH	City-el Standard	50mV/25 amp charge shunt. Cruising Equipment meter. Hot wired capacity gage.
4136	pev	Trojan 30XH	City-el Standard	
4137	pev			
4138	Warf, Ukiah			
4139	McClellan	Teledyne Sealed	City-el Teledyne	
4140	pev			
4141	pev			
4142	McClellan	GNB 1180	City-el GNB	Replaced center battery on 12-5-94. Hot wired capacity gage.
4143	Ukiah	GNB 1180	City-el GNB	Compound wound only.
4144	Baer	Trojan 30XH	City-el Standard	Old style DAS. Reversed main shunt wires. No AC watt-hours. Solar charging. Regen.
4145	pev			
4146	Twombley	Teledyne Sealed	City-el Teledyne	
4147	Cartwright	Trojan 30XH	City-el Standard	Capacity gage range extender installed.
4148	McClellan	Trojan 30XH	City-el Standard	
4149	McClellan	Trojan 30XH	City-el Standard	
4150	McClellan	Trojan 30XH	City-el Standard	
4151	McClellan	Trojan 30XH	City-el Standard	
4152	Warf, Ukiah	Trojan 30XH	Zivan 220V	
4153	McClellan	Teledyne Sealed	City-el Teledyne	
4154	McClellan	Trojan 30XH	City-el Standard	
4155	McClellan	Trojan 30XH	City-el Standard	
4156	pev			

3344	McClellan	Trojan SCS 225	City-el Standard	Uses a modified SMUD meter for the DAS kWh.
3574	McClellan	Trojan 30XH	City-el Standard	

Monthly Data Analysis for City-El

Print Date: 9-29-95

Month of: Sep. 95

McClellan AFB Subset

Vehicle Identification Number	ID #	User	Data Date	Watt hrs	Odometer	Specific G	H2O	Dots	%last chg	Lights
			RAW DATA							
UH5MSE04XPRS03990	3990	McClellan	9-27-95	918653	755.1	1.3	0.35	12	100	none
UH5MSE041PRS03991	3991	McClellan	9-26-95	607810	966.1	1.275	1	10	100	none
UH5MSE043PRS03992	3992	McClellan(I)	8-21-95	591257	1202.4	No Data for this month.				
UH5MSE045PRS03993	3993	Teledyne								
UH5MSE047PRS03994	3994	Childers								
UH5MSE049PRS03995	3995	McClellan	9-27-95	338437	640.6	1.27	0.39	12	82	etg
UH5MSE040PRS03996	3996	McClellan	9-27-95	876063	600.2	1.3	1.2	12	100	none
UH5MSE042PRS03997	3997	McClellan(I)	8-21-95	413392	347.4	No Data for this month.				
UH5MSE044PRS03998	3998	McClellan	9-26-95	938720	358.6	1.3	0.28	12	100	none
UH5MSE046PRS03999	3999	McClellan	9-26-95	25089.2	490.9	1.225	0.51	12		none
UH5MSE047PRS04000	4000	McClellan	9-26-95	854806	1099.3	1.25	0.61	12		none
UH5MSE049PRS04029	4029	McClellan	9-27-95	810013	584.7	1.275	0.26	12	100	none
UH5MSE046PRS04030	4030	Ukiah								
UH5MSE047PRS04031	4031	Ukiah								
UH5MSE049PRS04032	4032	Whitney								
UH5MSE040PRS04033	4033	pev								
UH5MSE045PRS04125	4125	McClellan	9-27-95	412673	346.9	1.3	1	12	100	none
UH5MSE047PRS04126	4126	Ukiah								
UH5MSE049PRS04127	4127	McLoudry								
UH5MSE040PRS04128	4128	Warf, Ukiah								
UH5MSE042PRS04129	4129	Townsend								
UH5MSE049PRS04130	4130	McClellan	9-27-95	871976	380.4	1.28	0.18	11	100	none
UH5MSE040PRS04131	4131	McClellan	9-27-95	804674	1022.8	1.225	0.38	9	100	none
UH5MSE042PRS04132	4132	McClellan	8-29-95	1000118	987.8	Broken Drive				
UH5MSE044PRS04133	4133	McClellan	9-27-95	747153	972.4	1.3	1	12	100	none
UH5MSE046PRS04134	4134	McClellan	9-27-95	635999	364.9	1.225	0.15	8		etg
UH5MSE048PRS04135	4135	PEV use								
UH5MSE04XPRS04136	4136	pev								
UH5MHE043PRS04137	4137	pev								
UH5MHE045PRS04138	4138	Warf, Ukiah								
UH5MHE047PRS04139	4139	McClellan	9-26-95	1098345	1913.6	N/A	N/A	12	100	none
UH5MHE043PRS04140	4140	pev								
UH5MSE043PRS04141	4141	pev								
UH5MSE045PRS04142	4142	McClellan	9-26-95	443226	478.7	N/A	N/A	12	100	none
UH5MSE047PRS04143	4143	Ukiah								
UH5MSE049PRS04144	4144	Baer								
UH5MSE040PRS04145	4145	pev								
UH5MSE042PRS04146	4146	Twombley								
UH5MSE044PRS04147	4147	Cartwright								
UH5MSE046PRS04148	4148	McClellan	9-27-95	898917	960.3	1.3	0.8	12	100	none
UH5MSE048PRS04149	4149	McClellan	9-27-95	990872	628.2	1.26	1.55	9	82	etg
UH5MSE044PRS04150	4150	McClellan	9-27-95	8680721	517.6	1.3	0.56	12	100	none
UH5MSE046PRS04151	4151	McClellan	9-27-95	791320	585.2	1.3	0.33	12	100	none
UH5MSE048PRS04152	4152	Warf, Ukiah								
UH5MSE04XPRS04153	4153	McClellan	9-26-95	1941234	2570.8	N/A	N/A	12	100	none
UH5MSE041PRS04154	4154	McClellan	9-26-95	830273	966.4	1.3	0.41	12	100	none
UH5MSE043PRS04155	4155	McClellan	9-28-95	332770	1973.8	1.125	0.39	8	100	none
UH5MSE045PRS04156	4156	pev								

4 Wheel Persports

S03344	3344	McClellan	6-15-95	166127	1056.3	Out of Service
S03574	3574	McClellan	6-15-95	200867	799.7	No Data for this month.

This document includes manual data collection for the City-El electric vehicle as specifed in SMUD Participation Agreement F-102 and as part of ARPA grant MDA972-93-1-0025

Monthly Data Analysis for City-El

Print Date: 9-29-95

Sep. 95

McClellan AFB Subset

ID #	User	SINCE LAST MONTH Days	W*h	Miles	Miles/day	W*h/Mile	TO DATE TOTALS Days	W*h	Miles	Miles/day	W*h/Mile	Mo.	Tot.
3990	McClellan	28		8.7	0.3		651	826785	708.5	1.1	1167.0	1	1
3991	McClellan	28	40900.5	96.1	3.4	425.6	650	547026	921	1.4	593.9	1	1
3992	McClellan(I)						614	532129	1181	1.9	450.6		1
3993	Teledyne												
3994	Childers												
3995	McClellan	28	28095.3	7.5	0.3	3746.0	651	639771	625.6	1.0	1022.7	1	1
3996	McClellan	29	54592.2	76.8	2.6	710.8	651	788455	567.7	0.9	1388.9	1	1
3997	McClellan(I)						614	372051	339.5	0.6	1095.9		1
3998	McClellan	28	44474.4	0	0.0		663	813136	304.9	0.5	2666.9	1	1
3999	McClellan	28	17837.2	18.1	0.6	985.5	650	515542	455.6	0.7	1131.6	1	1
4000	McClellan	28	28905.3	28.8	1.0	1003.7	650	769323	1032.9	1.6	744.8	1	1
4029	McClellan	29	31726.8	2.7	0.1	11750.7	651	729010	559.6	0.9	1302.7	1	1
4030	Ukiah												
4031	Ukiah												
4032	Whitney												
4033	pev												
4125	McClellan	28	39854.7	19.3	0.7	2065.0	677	593198	342.3	0.5	1733.0	1	1
4126	Ukiah												
4127	McLoudry												
4128	Warf, Ukiah												
4129	Townsend												
4130	McClellan	28	32239.8	20.7	0.7	1557.5	677	784777	374.2	0.6	2097.2	1	1
4131	McClellan	27	35991	39.6	1.5	908.9	664	1038788	1017.9	1.5	1020.5	1	1
4132	McClellan						648	900104	983.1	1.5	915.6		1
4133	McClellan	28	63478.8	171.8	6.1	369.5	677	672436	966	1.4	696.1	1	1
4134	McClellan	28	34704.9	5.4	0.2	6426.8	677	572397	357.8	0.5	1599.8	1	1
4135	PEV use												
4136	pev												
4137	pev												
4138	Warf, Ukiah												
4139	McClellan	27	47055.6	106.5	3.9	441.8	676	988507	1907.5	2.8	518.2	1	1
4140	pev												
4141	pev												
4142	McClellan	27	32413.5	17.7	0.7	1831.3	447	398902	473.6	1.1	842.3	1	1
4143	Ukiah												
4144	Baer												
4145	pev												
4146	Twombley												
4147	Cartwright												
4148	McClellan	27	44853.3	68.8	2.5	651.9	664	809023	952.7	1.4	849.2	1	1
4149	McClellan	28	54171.9	35.8	1.3	1513.2	664	891784	622.5	0.9	1432.6	1	1
4150	McClellan	28	7071507	12.3	0.4	574919.3	664	7812647	512.3	0.8	15250.1	1	1
4151	McClellan	29	27593.1	1.7	0.1	16231.2	664	712186	579.2	0.9	1229.6	1	1
4152	Warf, Ukiah												
4153	McClellan	28	47094.3	70.1	2.5	671.8	663	1747109	2563.8	3.9	681.5	1	1
4154	McClellan	28	42730.2	41.8	1.5	1022.3	663	747244	959.4	1.4	778.9	1	1
4155	McClellan	28	8267.4	7.2	0.3	1148.2	665	1028702	1966.8	3.0	523.0	1	1
4156	pev												
		Totals:	7828487	857.4				2.6E+07	21275.4			22	25
		Average:	355840	39.0	1.4	28562.8		1049241	851.0	1.3	1669.3		
		Std. Dev:	1.5E+6	42.4	1.5	124752.8		1.4E+6	550.9	0.8	2818.3		
3344	McClellan						177	78261	295.6	1.7	264.8		1
3574	McClellan						140	180761	214.8	1.5	841.5		1

Totals and Averages are not entirely correct due to holes in data.

Hydria Watt-hour Correction Factor = 0.9

This correction factor corrects the Watt-hour reading of the Hydria KWH meter. The Hydria meter reads 10% too high.

Monthly Data Analysis for City-El

Print Date: 9-29-95

Sep. 95

McClellan AFB Subset

ID #	User	DATA ACQUISITION SYSTEM, ANALYSIS GUIDE Batteries	Charger	Special
3990	McClellan	Trojan 30XH	City-el Standard	
3991	McClellan	Trojan 30XH	City-el Standard	
3992	McClellan(I)	Trojan 30XH	City-el Standard	
3993	Teledyne			
3994	Childers			
3995	McClellan	Trojan 30XH	City-el Standard	
3996	McClellan	Trojan 30XH	City-el Standard	
3997	McClellan(I)	Trojan 30XH	City-el Standard	
3998	McClellan	Trojan 30XH	City-el Standard	
3999	McClellan	Trojan 30XH	Pepco Turbo-Z	No Capacity Gage. Hot wired gage.
4000	McClellan	Trojan 30XH	City-el Standard	
4029	McClellan	Trojan 30XH	City-el Standard	
4030	Ukiah			
4031	Ukiah			
4032	Whitney			
4033	pev			
4125	McClellan	Trojan 30XH	City-el Standard	
4126	Ukiah			
4127	McLoudry			
4128	Warf, Ukiah			
4129	Townsend			
4130	McClellan	Trojan 30XH	City-el Standard	
4131	McClellan	Trojan 30XH	City-el Standard	
4132	McClellan	Trojan 30XH	City-el Standard	
4133	McClellan	Trojan 30XH	City-el Standard	Hot wired capacity gage.
4134	McClellan	Trojan 30XH	City-el Standard	Hot wired capacity gage.
4135	PEV use			
4136	pev			
4137	pev			
4138	Warf, Ukiah			
4139	McClellan	Teledyne Sealed	City-el Teledyne	
4140	pev			
4141	pev			
4142	McClellan	GNB 1180	City-el GNB	Replaced center battery on 12-5-94. Hot wired capacity gage.
4143	Ukiah			
4144	Baer			
4145	pev			
4146	Twombley			
4147	Cartwright			
4148	McClellan	Trojan 30XH	City-el Standard	
4149	McClellan	Trojan 30XH	City-el Standard	
4150	McClellan	Trojan 30XH	City-el Standard	
4151	McClellan	Trojan 30XH	City-el Standard	
4152	Warf, Ukiah			
4153	McClellan	Teledyne Sealed	City-el Teledyne	
4154	McClellan	Trojan 30XH	City-el Standard	
4155	McClellan	Trojan 30XH	City-el Standard	
4156	pev			

3344	McClellan	Trojan SCS 225	City-el Standard	Uses a modified SMUD meter for the DAS kWh.
3574	McClellan	Trojan 30XH	City-el Standard	

Monthly Data Analysis for City-El

Print Date: 9-29-95

Month of: Sep. 95

More Than 50 Miles Since Last Month Subset

Vehicle Identification Number	ID #	User	Data Date	Watt hrs	Odometer	RAW DATA Specific G	H2O	Dots	%last chg	Lights
UH5MSE04XPRS03990	3990	McClellan								
UH5MSE041PRS03991	3991	McClellan	9-26-95	607810	966.1	1.275	1	10	100	none
UH5MSE043PRS03992	3992	McClellan(l)								
UH5MSE045PRS03993	3993	Teledyne								
UH5MSE047PRS03994	3994	Childers	9-25-95	1322260	3525	1	2	11	?	none
UH5MSE049PRS03995	3995	McClellan								
UH5MSE040PRS03996	3996	McClellan	9-27-95	876063	600.2	1.3	1.2	12	100	none
UH5MSE042PRS03997	3997	McClellan(l)								
UH5MSE044PRS03998	3998	McClellan								
UH5MSE046PRS03999	3999	McClellan								
UH5MSE047PRS04000	4000	McClellan								
UH5MSE049PRS04029	4029	McClellan								
UH5MSE046PRS04030	4030	Ukiah								
UH5MSE047PRS04031	4031	Ukiah								
UH5MSE049PRS04032	4032	Whitney	9-12-95	?	4999.6	?	0.75	9	82	etg
UH5MSE040PRS04033	4033	pev								
UH5MSE045PRS04125	4125	McClellan								
UH5MSE047PRS04126	4126	Ukiah								
UH5MSE049PRS04127	4127	McLoudry	9-11-95	884214	1456.8	?	1.7	12		none
UH5MSE040PRS04128	4128	Warf, Ukiah								
UH5MSE042PRS04129	4129	Townsend								
UH5MSE049PRS04130	4130	McClellan								
UH5MSE040PRS04131	4131	McClellan								
UH5MSE042PRS04132	4132	McClellan								
UH5MSE044PRS04133	4133	McClellan	9-27-95	747153	972.4	1.3	1	12	100	none
UH5MSE046PRS04134	4134	McClellan								
UH5MSE048PRS04135	4135	PEV use								
UH5MSE04XPRS04136	4136	pev								
UH5MHE043PRS04137	4137	pev								
UH5MHE045PRS04138	4138	Warf, Ukiah								
UH5MHE047PRS04139	4139	McClellan	9-26-95	1098345	1913.6	N/A	N/A	12	100	none
UH5MHE043PRS04140	4140	pev								
UH5MSE043PRS04141	4141	pev								
UH5MSE045PRS04142	4142	McClellan								
UH5MSE047PRS04143	4143	Ukiah								
UH5MSE049PRS04144	4144	Baer								
UH5MSE040PRS04145	4145	pev								
UH5MSE042PRS04146	4146	Twombley	9-12-95	203362	329.2	N/A	N/A	10		etg
UH5MSE044PRS04147	4147	Cartwright								
UH5MSE046PRS04148	4148	McClellan	9-27-95	898917	960.3	1.3	0.8	12	100	none
UH5MSE048PRS04149	4149	McClellan								
UH5MSE044PRS04150	4150	McClellan								
UH5MSE046PRS04151	4151	McClellan								
UH5MSE048PRS04152	4152	Warf, Ukiah								
UH5MSE04XPRS04153	4153	McClellan	9-26-95	1941234	2570.8	N/A	N/A	12	100	none
UH5MSE041PRS04154	4154	McClellan								
UH5MSE043PRS04155	4155	McClellan								
UH5MSE045PRS04156	4156	pev								

4 Wheel Persports

S03344	3344	McClellan	6-15-95	166127	1056.3	Out of Service
S03574	3574	McClellan	6-15-95	200867	799.7	No Data for this month.

This document includes manual data collection for the City-El electric vehicle as specifed in SMUD Participation Agreement F-102 and as part of ARPA grant MDA972-93-1-0025

Monthly Data Analysis for City-El

Print Date: 9-29-95

Sep. 95

More Than 50 Miles Since Last Month Subset

ID #	User	SINCE LAST MONTH Days	W*h	Miles	Miles/day	W*h/Mile	TO DATE TOTALS Days	W*h	Miles	Miles/day	W*h/Mile	Mo.	Tot.
3990	McClellan												
3991	McClellan	28	40900.5	96.1	3.4	425.6	650	547026	921	1.4	593.9	1	1
3992	McClellan(I)												
3993	Teledyne												
3994	Childers	36	99526.5	325.7	9.0	305.6	572	1165245	3468.8	6.1	335.9	1	1
3995	McClellan												
3996	McClellan	29	54592.2	76.8	2.6	710.8	651	788455	567.7	0.9	1388.9	1	1
3997	McClellan(I)												
3998	McClellan												
3999	McClellan												
4000	McClellan												
4029	McClellan												
4030	Ukiah												
4031	Ukiah												
4032	Whitney	32		286.3	8.9		661		4992.2	7.6		1	1
4033	pev												
4125	McClellan												
4126	Ukiah												
4127	McLoudry	31	43492.5	66	2.1	659.0	914	791408	1450.8	1.6	545.5	1	1
4128	Warf, Ukiah												
4129	Townsend												
4130	McClellan												
4131	McClellan												
4132	McClellan												
4133	McClellan	28	63478.8	171.8	6.1	369.5	677	672436	966	1.4	696.1	1	1
4134	McClellan												
4135	PEV use												
4136	pev												
4137	pev												
4138	Warf, Ukiah												
4139	McClellan	27	47055.6	106.5	3.9	441.8	676	988507	1907.5	2.8	518.2	1	1
4140	pev												
4141	pev												
4142	McClellan												
4143	Ukiah												
4144	Baer												
4145	pev												
4146	Twombley	23	19749.6	51.7	2.2	382.0	449	183024	322.2	0.7	568.0	1	1
4147	Cartwright												
4148	McClellan	27	44853.3	68.8	2.5	651.9	664	809023	952.7	1.4	849.2	1	1
4149	McClellan												
4150	McClellan												
4151	McClellan												
4152	Warf, Ukiah												
4153	McClellan	28	47094.3	70.1	2.5	671.8	663	1747109	2563.8	3.9	681.5	1	1
4154	McClellan												
4155	McClellan												
4156	pev												
		Totals:	460743	1319.8				7692233	18112.7			10	10
		Average:	46074	132.0	4.4	461.8		769223	1811.3	2.8	617.7		
		Std. Dev:	20.3E+3	93.0	2.6	148.5		408.3E+3	1399.3	2.2	281.6		
3344	McClellan						177	78261	295.6	1.7	264.8		1
3574	McClellan						140	180761	214.8	1.5	841.5		1

Totals and Averages are not entirely correct due to holes in data.

Hydria Watt-hour Correction Factor = 0.9

This correction factor corrects the Watt-hour reading of the Hydria KWH meter. The Hydria meter reads 10% too high.

Monthly Data Analysis for City-El

Print Date: 9-29-95

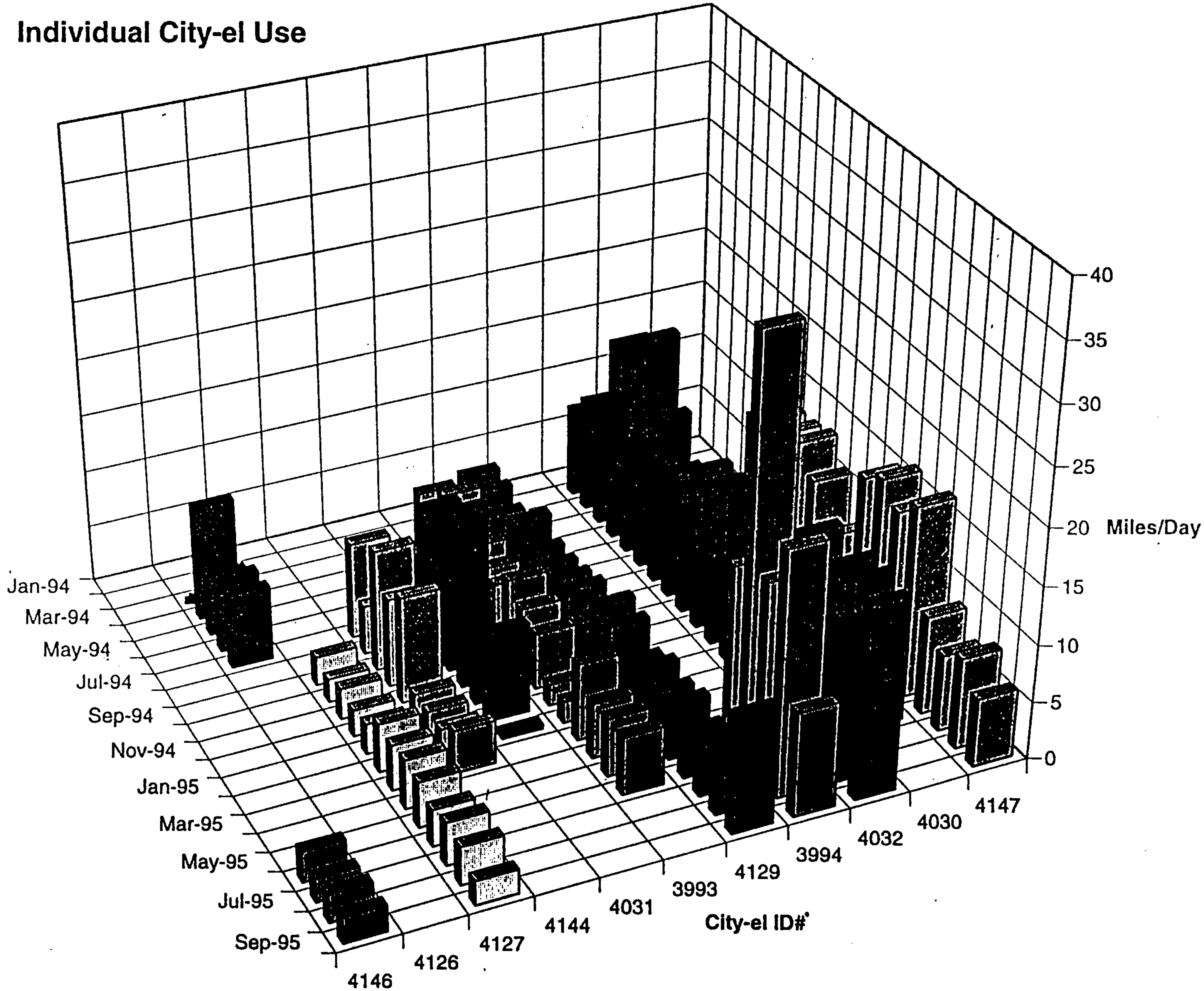
Sep. 95

More Than 50 Miles Since Last Month Subset

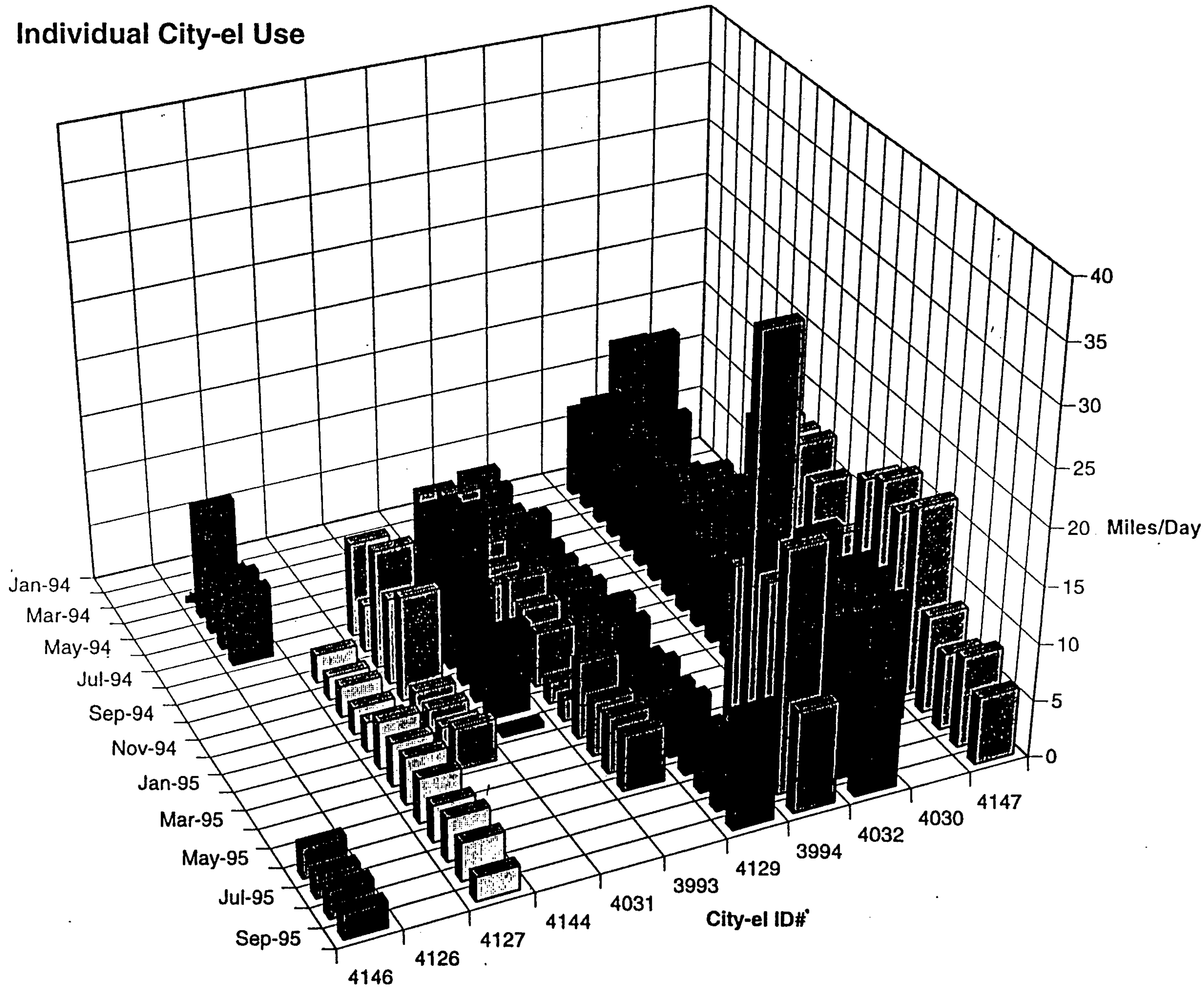
ID #	User	DATA ACQUISITION SYSTEM, ANALYSIS GUIDE Batteries	Charger	Special
3990	McClellan			
3991	McClellan	Trojan 30XH	City-el Standard	
3992	McClellan(I)			
3993	Teledyne			
3994	Childers	Trojan 30XH	City-el Standard	Compund, speedkit, and series switching on motor. Hot wired gage.
3995	McClellan			
3996	McClellan	Trojan 30XH	City-el Standard	
3997	McClellan(I)			
3998	McClellan			
3999	McClellan			
4000	McClellan			
4029	McClellan			
4030	Ukiah			
4031	Ukiah			
4032	Whitney	Trojan SCS 225	City-el Standard	Hot wired capacity gage.
4033	pev			
4125	McClellan			
4126	Ukiah			
4127	McLoudry	Trojan 30XH	City-el Standard	
4128	Warf, Ukiah			
4129	Townsend			
4130	McClellan			
4131	McClellan			
4132	McClellan			
4133	McClellan	Trojan 30XH	City-el Standard	Hot wired capacity gage.
4134	McClellan			
4135	PEV use			
4136	pev			
4137	pev			
4138	Warf, Ukiah			
4139	McClellan	Teledyne Sealed	City-el Teledyne	
4140	pev			
4141	pev			
4142	McClellan			
4143	Ukiah			
4144	Baer			
4145	pev			
4146	Twombley	Teledyne Sealed	City-el Teledyne	
4147	Cartwright			
4148	McClellan	Trojan 30XH	City-el Standard	
4149	McClellan			
4150	McClellan			
4151	McClellan			
4152	Warf, Ukiah			
4153	McClellan	Teledyne Sealed	City-el Teledyne	
4154	McClellan			
4155	McClellan			
4156	pev			

3344	McClellan	Trojan SCS 225	City-el Standard	Uses a modified SMUD meter for the DAS kWh.
3574	McClellan	Trojan 30XH	City-el Standard	

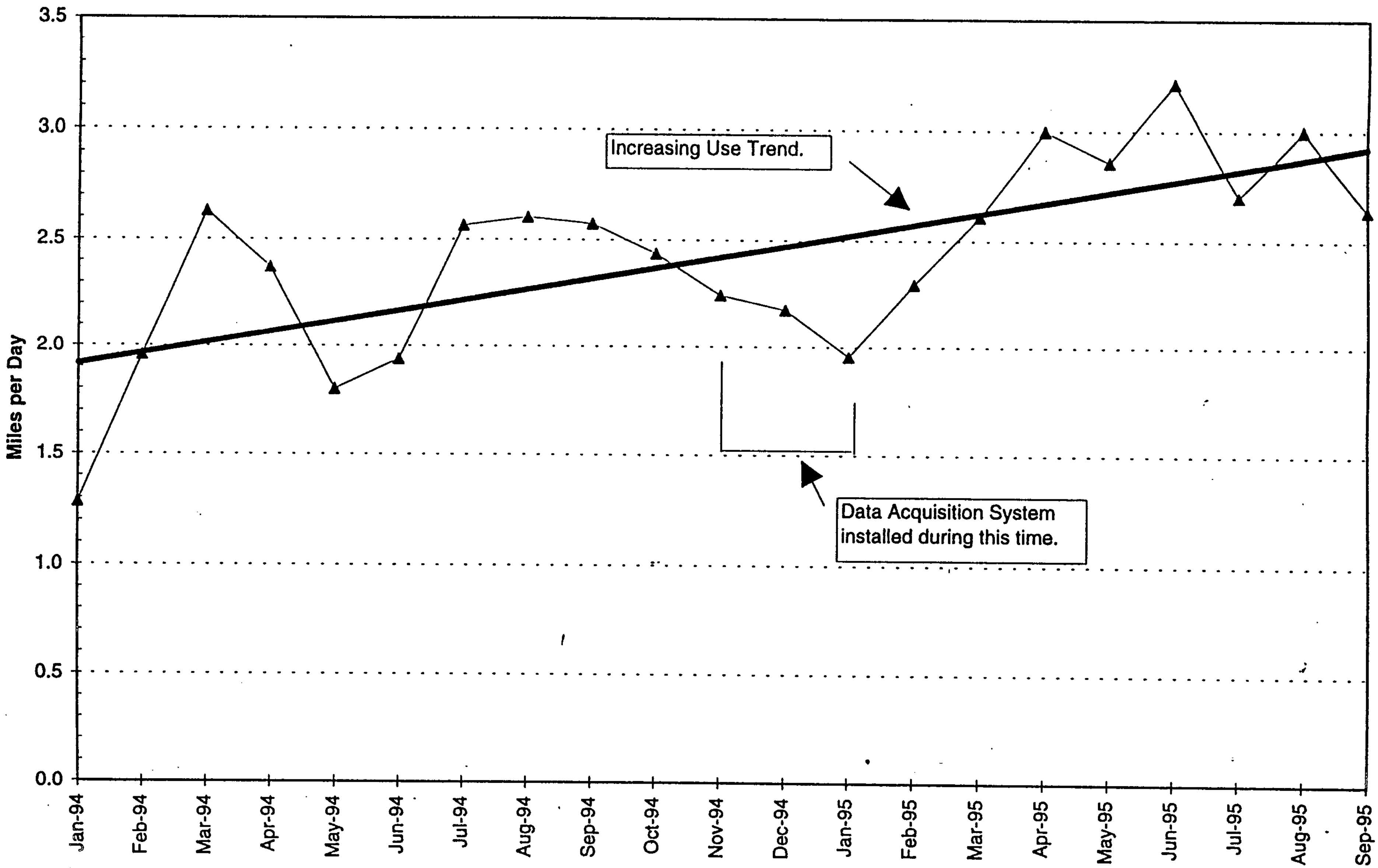
Individual City-el Use



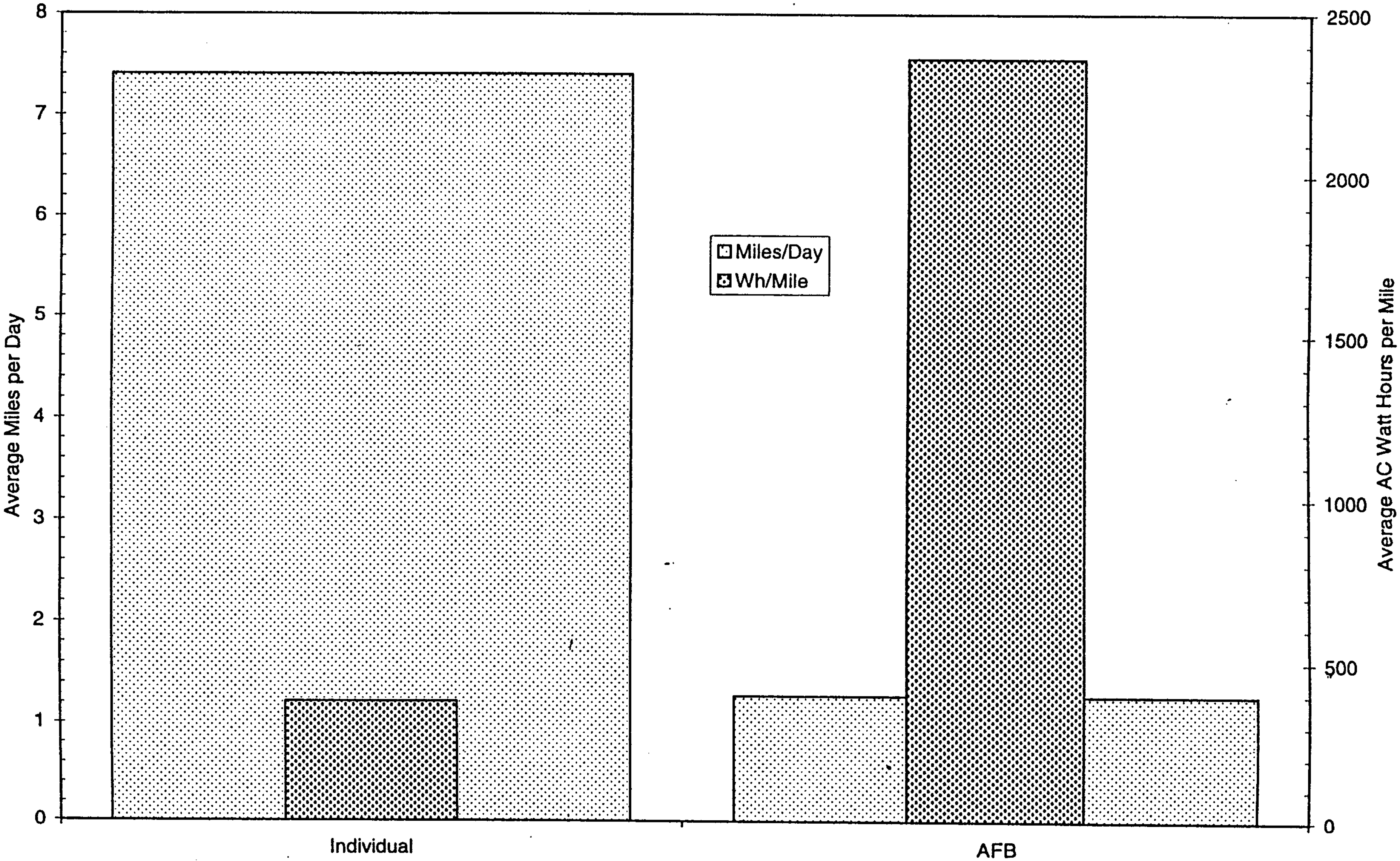
Individual City-el Use



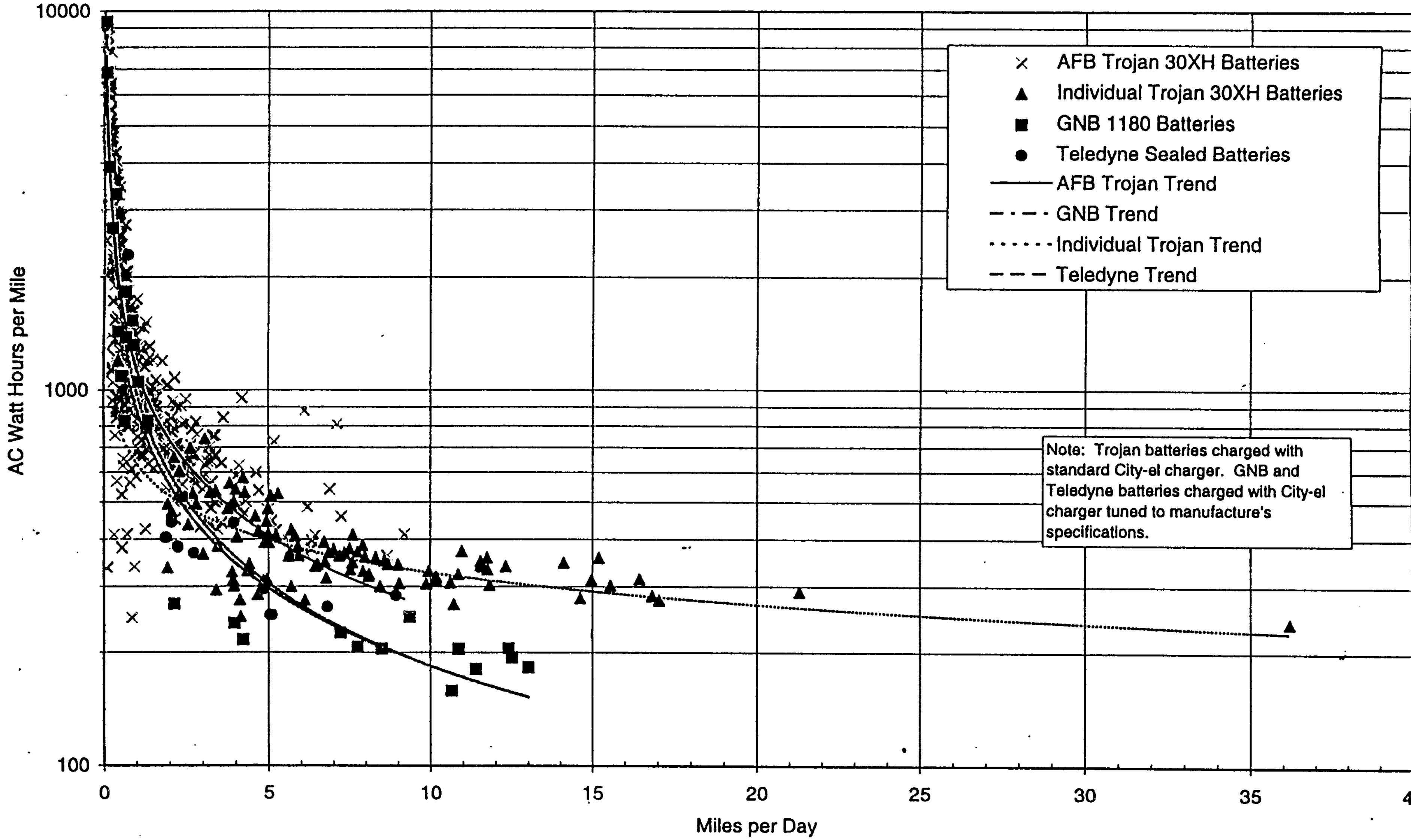
Average City-el Use During NEV Program



Individual City-el Users Compared to McClellan AFB Users



Amount of Use Effects on City-el AC Energy Use



INTRODUCTION.

This file contains information on the DAS data files for the City-el listed below. The DAS data was obtained from a microprocessor based data aquisition system (DAS). For more information on this system or the data contained on this file or the DAS data files contact:

Pacific Electric Vehicles
8500 Weyand Avenue
Sacramento. CA 95828
Phone#: (916) 381-3509
Fax#: (916) 381-2189

This document includes 3 parts.
Part 1: CITY-EL 3999 DAS DATA FILE INFORMATION.
Part 2: THE FILE NAMING CONVENTION.
Part 3: THE BIN LAYOUT FOR THE TRIP DATA.

CITY-EL 3999 DAS DATA FILE INFORMATION.
----

d9994354. Initial calibration test file.
d9995044. Normal download for February.
d9995082. Normal download for March.
d9995115. Normal download for April.
d9995143. Normal download for May. Download error. No data.
d9995153. Normal download check on DAS
d9995176. Normal download for June.
d9995204. Normal download for July. DAS won't download.
d9995214. Download before Pepco Charger installation.
Calibration is wrong and possible charge data problems.
d9995215. Recalibration for new charger and batteries.
d9995241. Normal download for August. Charge Data Problems.
d9995269. Normal download for September. Download error.
Missing charge data and trips 16. 17. and 21.
d9996137. Download before DAS removal. Data seems strange.

THE FILE NAMING CONVENTION.

The files that are downloaded from the DAS are named using the following convention.
File Name DNNNYDDD.1AX

D First letter for the coalition designation is "D"

NNN Next 3 digits are last 3 digits of the vehicle VIN#.

YDDD Next 4 digits are the Julian date of the download. The first number is the last digit of the year. For 1994. the number would be 4. The year is followed by the number of the day since January 1st which is day 001. January 5th would be 005. February 2nd would be 033. It continues in this way until

December 31st which is day 365 except for leap years.

1 First digit in the extension is the trip number which is "1".

A The second position in the extension is the file type designation.
Use "S" for statistical data which is the case when downloading the DAS. For monitored trips or charges where data was collected second by second with the computer, the letter is "T" for time series data.

X The last position is Pacific EV's informational letter.
"D" is used for a successful and normal download of the DAS.
"E" is used when a download was performed with the ERROR prompt showing.
"P" is used for the download made after the initial tests of the DAS.
H is used when the DAS is locked up and must be unplugged and replugged in to download the data.
"R" is used when monitoring a run with the computer.
"C" is used when monitoring a charge with the computer.

Example 1 For City-el 3994 successfully downloaded on June 15, 1994, the filename would be: D9944166.1SD

Example 2 For City-el 4126 downloaded on October 20, 1994 while the DAS was showing the ERROR prompt, the filename would be: D1264293.1SE

Example 3 For a charge monitored with the computer on City-el 4135 on June 9, 1995, the filename would be: D1355160.1TC

THE BIN LAYOUT FOR THE TRIP DATA.

Each trip includes 32 bins of data. Each bin includes the time spent in the bin and the average speed, acceleration, voltage, and current in each bin. The bin is defined by an acceleration and speed range. These definitions are listed below.

Bin	Acceleration (m/s^2)	Speed (m/s)
1	>2.5	<5
2	>1.5	<5
3	>0.5	<5
4	0	<5
5	<-0.5	<5
6	<-1.5	<5
7	<-2.5	<5
8	>2.5	<10
9	>1.5	<10
10	>0.5	<10
11	0	<10
12	<-0.5	<10

Appendix 3 Research Documents List

Neighborhood Electric Vehicle Market and Product Test and Development Project
Final Report
15 November, 1996

Pacific Electric Vehicles, LLC   Contact: Bill Warf 707-485-5799
Research Documents List;
Neighborhood Electric Vehicle Project, page 1, 11/15/96

Mini-el Manufacturing Plan 8/10/92

Mini-el Market Forecast 8/10/92

Data Management Plan, 29 September, 1993

Test Report, Charger Efficiency on the City-el Electric Vehicle 30 March, 1994

Safety Review Summary, 5 April, 1994

Test Report, Wear Evaluation on the City-el Electric Vehicle, 1 April, 1994

Rolling Resistance and Coefficient of Drag Testing, City-el. 12 April, 1994

Analysis of Monthly Data 19 April, 1994

Component Test Plan. 26 July, 1994

Test Report, Solectria Force Charger and Battery Test, 31 August, 1994

Presentation Materials, Tri Annual Review, 9-11 May, 1994

Test Report, City-el Charger Tuned for GNB Batteries 10 June, 1994

Presentation Materials: NEV Workshop, June 30, 1994

Test Report, City-el DC-DC Converter Efficiency, 29 September, 1994

Test Report, City-el Charger and Battery Test, 27 September, 1994

Test Report, City-el Constant Power Drains, 29 September, 1994

Pepco Turbo-Z Charger Use on a City-el, 31 December, 1994

City-el Data Acquisition System, Users Manual, 9 January, 1995

Consequences and Wiring for Long Term Use of Pepco Turbo Z Charger, 1 February, 1995

Pacific Electric Vehicles, LLC   Contact Bill Warf   707-485-5799
Research Documents List; Neighborhood Electric Vehicle Project
Page 2, 11/15/96

Canopy Fabrication Process Description, 4/19/95

Body Shell and Door Design, 6/8/95

Safety Characteristics, Peregrin NEV, 6/8/95

Persport Versus City-el Test Report, 6/29/95

Drive Design Report, 6/30/95

City-el, Preliminary Battery Life Report, 6/30/95

Final Wiring of Pepco Turbo Z Charger to the City-el, 4 August, 1995

NEV Prototype Steering System Design, 9/30/95

Prototype NEV Glazing Design 9/11/95

Brake System Design Report, 11/7/95

NEV Prototype Suspension Design 11/6/95

Zivan K05 36V Charger Test Report, 11/5/96

American Monarch Charger, 60 V, 11/2/96

Mirabor Charger Test Report, 12/1/96

Pepco Turbo Z, final notes, 11/6/96

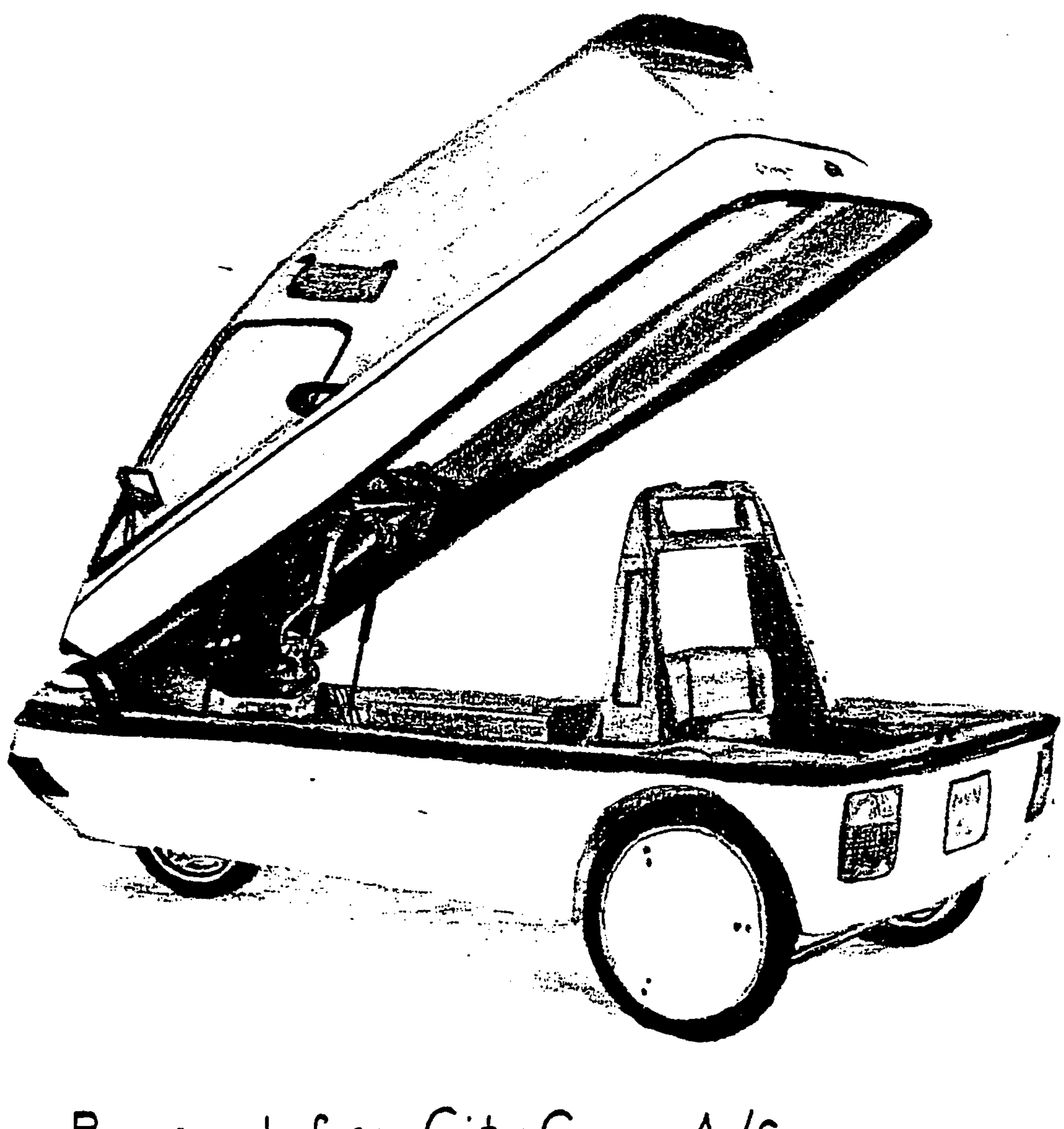
60 V four wheeled City-el, Testing Notes, 11/1/96

Monthly Data Submittals, December 93- September/95

NEV Project, Final Report, 11/15/96

MINI-EL USA
MANUFACTURING PLAN

Prepared by
William R. Warf P.E.
10 August 1992



Prepared for: CityCom A/S
Haraldsvej 66
DK-8900 Randers
Denmark

MANUFACTURING PLAN OVERVIEW:

This Manufacturing Plan provides a proposal for the complete costs and timing required to establish a Mini-el USA factory outlet. The plan includes a plant layout, equipment lists, and tooling lists. Time phased plans are provided for factory start-up and production ramp up. An inventory plan is presented to support the initial production. The inventory plan takes into account container size, shipping time, service parts estimated requirements, and of course the market estimate. This manufacturing plan provides a budget including facilities, equipment, inventory, and personnel costs, expressed as a pro-forma profit and loss statement, to the gross margin line. Quality Assurance, Testing, Engineering Change Control, Shipping, and Purchasing are also addressed.

The factory will be very responsive to customers. This fact will be assured by frequent distributor support by factory personnel, and by frequent dealer feed-back to the factory. The Master Production Schedule will be revised weekly using information regarding sales from the distribution system. Factory inventory will be kept to a minimum, consistent with the best possible customer service, to assure maximum cash flow. This will also assure neither the distributors nor the factory carry excessive inventory. Detailed information from the distribution system will allow us to tailor the build configuration to meet the maximum possible demand, and to revise the build schedule according to actual sales. Price incentives encourage customers to order Mini-el's 4 to 6 weeks in advance of delivery; so a significant portion of sales may be to fill existing orders. Two week to one month inventory supply is used for the initial plan.

The Manufacturing Philosophy is based maximizing the amount of time all workers in the factory add value to the vehicles on the line. Continuous improvement of all activities will be achieved by continually improving processes and eliminating waste.

Management systems assure detection of defects and tracing these defects to their actual cause before they end up in inventory or in customers hands.

Personnel issues are key to success. Factory support of dealers by employees in rotation will keep us close to the customers, and maximize product and service quality. All employees in the factory will begin by assembling Mini-el's so they have personal knowledge of the product. The goal will be to have all employees cross trained in all assembly and support functions. All employees will spend some time each year at dealer's facilities or at shows to gain direct customer product reactions.

The factory layout has been designed by first designing the assembly process, and then laying out the assembly line to match this process. The assembly process has been broken down into 14 steps plus 8 sub-assembly tasks occurring adjacent to the line.

Sub-assembly tasks will be performed concurrent with line tasks so value added to sub-assemblies is closely matched with completed vehicle production. This minimizes the cost of "work-in-process" inventory.

Only a minimum amount of inventory will be stored on line. Un-powered roller conveyors are used to feed parts to the line and sub-assembly areas, and to return empty, re-useable containers to the inventory area.

The computer system will be used to increment component inventory as parts are received, decrement inventory based on actual build, and to track the master production schedule. Inventory levels will match the build schedule to assure smooth throughput. Vehicle serial numbers are configuration controlled to match the bill of material revision number. The bill of material is maintained by Engineering and Material Planning.

SALES FORECAST:

A Sales forecast was developed in the U.S. Market Estimate, Mini-el document. This Sales forecast assumed a quick start-up to fill the gap in available Electric Vehicles beginning in late 1992. A share of approximately 10% of the minimum US Electric Vehicle Market is achieved starting in 1995. The Sales Forecast from the Market Estimate is utilized in this document as a base line manufacturing schedule or master production schedule. Filling the forecast demand is accomplished by exclusively importing Mini-el's from Denmark for the first year of operation, as discussed in the schedule section. During the factory start-up period, which lasts 6 months, demand is filled both by importing and domestic manufacturing of the Mini-el. The Sales Forecast is summarized as follows:

Year	1992+1993	1994	1995	1996	1997	1998
Units	800	2450	4100	5000	6000	6000

A more detailed look at the schedule of forecast sales as derived from the Market Estimate is presented on the Mini-el USA Factory Start-up Schedule, and in the Inventory Plan, both later parts of this Manufacturing Plan.

Mini-el USA START-UP SCHEDULE:

A milestone schedule for the first three years of operations is presented in Figure 1 (two pages). This section of the Manufacturing Plan presents a narrative of the schedule for both the importing and manufacturing periods as represented by the schedule. The schedule time line is presented by Month Number and by Quarter Number, to allow for flexibility as the business plan is completed.

Key Milestones:

As of this writing it is expected that US Mini-el Sales will reach 500 units by August, 1993 (month 11). This is the key milestone for agreeing to proceed with starting a Manufacturing Facility, and funding the associated start-up activities. Other key milestones include:

Line 1: Agreement to Proceed in Month 0, (expected 9/15/92)
Line 24: US DOT approval of Mini-el, to allow importing (12/15/92)
Lines 4 & 6: Initial US distributors established and trained (Oct. 1992) (Please see Figure 1)

Schedule Narrative:

The following narrative discusses assumed schedule events as they are foreseen by this plan. The approximate sequence is correct, but any mention of dates is for reference.

Schedule Narrative, First Quarter of Operations:
During the first quarter of operations 96 Mini-el's are imported. These are sold to Utilities or Public or Government entities, and are used to provide saleable inventory for the first two distributors in Davis and Sacramento. The completed Mini-el's are shipped 16 per container, which requires 6 containers be shipped in this period. The first two distributors are self funding. Their funding may include support from the local utility for sustaining operations during the start-up period.

At the beginning of this quarter details of Mini-el distribution are finalized. The distributor agreement is prepared, and executed by the first two dealers. Details of distributor operations, including incorporation of Utility and Government incentives, leasing, sales terms, and the like are included in the Distribution Plan portion of the Mini-el USA Business Plan. Dealers must agree to fax customer reaction surveys daily to the factory service center.

FIGURE 1 PAGE 1 of 2

PROJECT: MINI-EL USA FACTORY START-UP SCHEDULE

LINE NO.	MILESTONES	0	1	2 (I)	3	4	5 (II)	6	7	8 (III)	9	10	11 (IV)	12	13	14 (V)	15	16 (VI)	17	SCHED. START	SCHED. COMP.	EXPECTED COMP.	ACTUAL COMP.
1	AGREEMENT TO PROCEED	△																					
2	SHIP 2 CONTAINERS																						
3	TRAIN 4 TECHNICIANS	△																					
4	SACRAMENTO DEALERSHIP		△																				
5	DAVIS DEALERSHIP		△																				
6	SHIP 2 CONTAINERS																						
7	SHIP 2 CONTAINERS																						
8	96 UNITS CUM. SALES				△																		
9	SHIP 2 CONTAINERS				△△	△△	△△	△	△	△△	△	△											
10	300 UNITS CUM. SALES							△															
11	500 UNITS CUM. SALES												△										
12	FACTORY GO-AHEAD AGREE												△										
13	SERVICE CENTER				△								△								8/15/93		
14	FACTORY SITE												△										
15	FACTORY SET-UP																						
16	PRODUCTION LINE START-UP																						
17	4 UNIT/DAY BUILD RATE																		△				
18	CUM. SALES 800																△						
19	CUM. SALES 1000																		△				
20	10 WEST COAST DEALERS														△								
21	DISTRIBUTOR AGREEMENT DOC.	△																					
22	NHTSA/DOT RESEARCH																						
23	NHTSA/DOT APPROVAL																						
24	APPROVAL REC'D				△																		
25																							
26	WEEKLY COMPLT CAR CONTAINERS																						
27	CONTAINERS OF PARTS (32 UNITS)																						
28	CONTAINER SHIPS EVERY 8 DAYS														△	△	△	△					
29	QUARTER Nº			I			II			III			IV			V			VI				
30	SALES		20	36	40	50	50	54	50	50	50	50	50	75	75	75	75	100	100				
31	CUM.				96				300		400		500				800		1000				

PREPARED BY: C.L.W.

APPROVED

LEGEND: SCHED. △ EXP □
ACTUAL ▲ ACT ■

FORMANCE

SCHEDULE NO.:
DATE: 8/10/92 REV.
PAGE 1 OF 2

FIGURE 1 PAGE 2 of 2

PROJECT: MINI-EL USA FACTORY START-UP SCHEDULE

LINE NO.	QUARTER Nº / MONTH NUMBER / MILESTONES	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	SCHED. START	SCHED. COMP.	EXPECTED COMP.	ACTUAL COMP.
	QUARTER Nº		VII			VIII			IX			X			XI			XII					
32	INVENTORY LEVEL																						
33	32 UNIT-PARTS/CONTAINER																						
34	CONTAINER SHIP EVERY 8 DAYS	△																					
35	CONTAINER SHIP EVERY 6 DAYS																						
36	CONTAINER SHIP EVERY 5 DAYS																						
37	CONTAINER SHIP EVERY 4 DAYS																						
38	CONTAINER SHIP EVERY 3 DAYS																						
39	CONTAINER SHIP EVERY 2 DAYS																						
40																							
41	PRODUCTION 6/DAY	△																					
42	PRODUCTION 10/DAY				△																		
43	PRODUCTION 12/DAY							△															
44	PRODUCTION 14/DAY										△												
45	PRODUCTION 17/DAY													△									
46																							
47	END REGULAR COMPLT CAR SHIP FROM DK				△																		
49	10 WEST COAST DISTRIBUTORS		△																				
50	3 EAST COAST DISTRIBUTORS							△			△												
51	6 EAST COAST DISTRIBUTORS													△			△						
52																							
53	U.S. PARTS SOURCE:																						
54	QUOTING				△			△															
55	PURCHASING						△																
56	$ 60% US CONTENT																		△				
57																							
58																							
59																							
60	QUARTER Nº VI			VII			VIII			IX			X			XI			XII				
61	SALES	200	200	200	200	200	200	200	250	300	300	300	300	350	300	350	350	350	350				
62	CUMULATIVE SALES					2000					3250			4200					5900				

PREPARED BY: C.L.W.
APPROVED BY: ______

LEGEND: SCHED. △ EXP □
ACTUAL ▲ ACT ■

PERFORMANCE

SCHEDULE NO.: ______
DATE: 8/10/92 REV. ______
PAGE 2 OF 2

Also during the first quarter of operations, the process of obtaining government approval of the mini-el is completed. This activity requires research of National Highway Traffic and Safety Administration (NHTSA) and Department of Transportation (DOT) requirements. The necessary documentation must be completed, and approval to import and manufacture obtained. This plan assumes that as a minimum temporary permission to import up to 500 units during the first 12 months of operations is achieved. During this trial period, agreements may be reached with the authorities for Safety Requirements, and registration limitations. Full approval and release must be achieved by Month 8. No sales to private individuals are planned without at least temporary government permission. Sales may lag the plan shown if government approval is not obtained as shown on the schedule.

At the end of the first quarter, a Factory Service Center will be set up, to inventory spare parts and provide factory support to the first two distributors. Inventory scheduled for delivery to these dealers may be staged at the Factory Service Center. The factory service center personnel will qualify the Mini-el for applicable Tax or other incentives. These personnel will also manage field service, training, customer survey reviews, and other start-up activities.

Schedule Narrative, Second Quarter of Operations:
During the second quarter of operations, completed 200 Mini-el's are imported to the service center and sold by the first two distributors. Cumulative sales of 300 units are achieved. Research is performed by the Factory Service Center staff to further confirm market acceptance, obtain data about US reaction to the Mini-el, and to plan product improvements. Prospective West Coast Dealership plans and locations are confirmed.

Schedule Narrative, Third Quarter of Operations:
Third quarter activities are similar to those in the second quarter. By the end of the third quarter, 448 Mini-el's will have been imported, and 400 units sold.

Schedule Narrative, Fourth Quarter of Operations:
During the fourth quarter of operations, price incentives to individual customers may be offered for orders placed six weeks in advance of delivery. This will facilitate incrementing sales to 75 units per month by the end of the fourth quarter. The imported quantity will reach 624 units, and sales will reach 575 units. Weekly container shipments of completed Mini-el's from Denmark will start early in this quarter.

The key 500 units in sales milestone is expected in the middle of the fourth quarter of operations (8/93 as of this writing). This milestone will trigger funding of the factory. The associated milestones are shown as a GO-AHEAD AGREEMENT, and FACTORY SITE SELECTION. Other activities include starting to hire key factory personnel, and factory set-up activities. The set-up activities

include tooling and equipment acquisition and set-up, fixture manufacturing, Service Center relocation to the Factory Site, and setting up the inventory system to handle component parts inventory.

Schedule Narrative, Fifth Quarter of Operations:
During the fifth quarter of operations, the process of setting up the factory is virtually completed. Initial production of Mini-el's is accomplished, to test all tooling and fixturing. Mini-el production is started very slowly and deliberately to assure all tools, fixtures, and test equipment are correct, and to allow thorough training of personnel.

During this period, two containers of parts for Mini-el factory inventory are be shipped and delivered. This inventory quantity amounts to 64 units, plus service parts spares. By the end of the fourth quarter, a cumulative total of 880 Mini-el's are imported, and the first 4 units are produced by the factory. Mini-el sales of 800 units should be achieved.

Additional Dealerships are added to the distribution system starting in the fifth quarter of operations. This effort will result in 12 West Coast dealerships total by early in the eighth quarter of operations.

Schedule Narrative, Sixth Quarter of Operations:
During the sixth quarter of operations, The production line achieves a build rate of four units per day, and ramp up to six units per day by the end of the quarter. Containers of parts arrive every 8 days, incrementally increasing to arrival every 6 days. Shipments of complete units from Denmark continue to support growing market penetration, as new distribution outlets are established.

By the end of the sixth quarter, 138 units will have been built by the Mini-el USA factory, and a cumulative total of 1168 units have been imported. Additional advertising will be initiated. Price incentives for "to be delivered" orders may be increased. Sales should reach a cumulative total of 1200 units. Inventory levels will swell slightly due to overlap of factory build and import of complete cars.

Schedule Narrative, Seventh Quarter of Operations:
Early in the seventh quarter of operations, the West Coast Distribution system will be fully in place. Sales should reach 1800 units.

Shipments of containers of parts from Denmark increase in frequency, arriving every 4 days by the end of the period. Deliveries of completed Mini-el's will decrease, as the factory ramps to a production level of 10 per day by the end of the quarter.

Mini-el USA Purchasing will begin the process of sending out Requests for Quotation for parts to be US sourced, or purchased directly by Mini-el USA.

By the end of the seventh quarter, 500 units should have been produced by Mini-el USA, and 1400 units imported completely assembled in Denmark. The end of this quarter should mark the end of regular importing of completed Mini-el's from Denmark, although this option will remain if needed to fill demand. (Later imports are shown in month 30, later in this plan to simulate the effect.)

Schedule Narrative, Eighth Quarter of Operations:
The production rate increases to 12 per day. The West Coast Distribution System is fully in place and selling at a rate of 14 to 20 units per dealer per month, giving monthly sales of 200 units. Significant sourcing of US parts commences. Containers of parts from Denmark increase in frequency to on every 3 days by the end of the quarter.

Schedule Narrative, Ninth Quarter of Operations:
The production level continues to ramp up to 14 units per day. Parts containers from Denmark continue to increase in frequency to one every 2 days by the end of the period.

By the end of the ninth quarter of operations, 3 East Coast Distributors are in place. These dealers will take shipments from the West Coast factory.

Mini-el US purchasing and operations personnel work with suppliers to establish domestic parts supply for all metal parts in the Mini-el. Many parts are purchased direct from off-shore suppliers.

Schedule Narrative, Tenth Quarter of Operations:
The factory production level increases to 17 per day, as total cumulative production reaches almost 2800 units at Mini-el USA.

Before the end of the tenth quarter, US sourcing results in a decrease in the frequency of container shipments from Denmark to one every 4 days.

East Coast distribution effort is increased as the process of adding distributors is continued.

Schedule Narrative, Eleventh Quarter of Operations:
Production at 17 Units per day continues as total US Mini-el sales passes 5000 units. Continued sourcing of parts by Mini-el USA purchasing group allows further reduction in Danish container shipments. The East Coast Distribution system is fully in place.

Schedule Narrative, Twelfth Quarter of Operations:
Mini-el USA achieves 60 % domestic parts content. Container shipments are again lowered to one every 6 days.

INVENTORY PLAN:

The Inventory Plan is presented in Tables 1 and 2. This plan includes both imported complete Mini-el's, and parts importing expressed in car sets needed to support the first two years production. The inventory plan takes into account container size, shipping time, and service parts estimated requirements. This inventory plan will be used to develop the cash requirements for business operation, as discussed in the Financial Plan section of the Business Plan.

This Inventory Plan assumes that from a factory perspective, Sales are equivalent to shipments to the Distribution System. Distributors will be required to pay net 15 days after shipment receipt, unless special terms are negotiated. Delivery of completed cars which have been ordered in advance will be provided with a price discount and may include longer terms of payment for distributors. These details are discussed in the Distribution Plan portion of the Business Plan.

The philosophy of Mini-el USA will be to operate at the minimum possible inventory level. This means that component inventory, complete cars inventory, and work in process inventory will match actual sales demand. Target Inventory levels will be about one month supply early in the plan period, when complete cars are imported. As the factory comes on line, shorter inventory amounts will be achieved, down to two week supply or better. This approach will help Mini-el USA achieve world class manufacturer status before the end of 1995.

The processes and systems required to keep manufacturing "work-in-process" inventory to a minimum will be described in the Manufacturing Process section of this document.

Purchasing:
Purchasing systems will favor working with suppliers who are located close to the Mini-el USA factory. This proximity will allow frequent contact with these suppliers, and will eventually allow daily shipment of components to Mini-el USA. The goal of the purchasing system will be to enter into multi-year sourcing agreements with suppliers who have proven the ability to deliver 99.9% conforming products, according to the release to ship schedule, at the agreed price. Proof will generally require a minimum of a six month track record of performance. Dual sourcing of difficult parts will be favored. Payment terms will be net 30 to 45 days, with better terms offered to suppliers with optimum performance.

TABLE 1

Inventory Plan : 9 / 92 Through 3 / 94

Month :	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sales *(Units)*	0	20	36	40	50	50	54	50	50	50	50	50	75	75	75	75	100	100	200
Sales *(Cumulative)*	0	20	56	96	146	196	250	300	350	400	450	500	575	650	725	800	900	1000	1200
Production From DK	32	64	0	64	64	32	64	32	64	32	32	64	80	80	80	96	96	96	96
Production From Factory	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	16	32	86
Production Total	32	64	0	64	64	32	64	32	64	32	32	64	80	80	80	100	112	128	182
Production *(Cumulative)*	32	96	96	160	224	256	320	352	416	448	480	544	624	704	784	884	996	1124	1306
Completed Unit Inventory	32	76	40	64	78	60	70	52	66	48	30	44	49	54	59	84	96	124	106
Invent. receipts C.S. parts	3	3	0	2	0	2	0	0	2	2	2	2	2	3	32	32	32	32	64
Parts Issues to Fact./Distr. C.S.	0	3	0	0	2	0	0	0	2	2	2	2	2	3	0	6	16	34	86
Net Inventory Parts (C.S.)	3	3	3	5	3	5	5	5	5	5	5	5	5	5	37	63	79	77	55
Total Inventory C.S. plus cars	35	79	43	69	81	65	75	57	71	53	35	49	51	59	96	147	175	201	161
Quarter #		<----	I	---->	<----	II	---->	<----	III	---->	<----	IV	---->	<----	V	---->	<----	VI	---->

C.S. [Ca[illegible]ets]

William R. W[illegible] 8/1/92

TABLE 2

Inventory Plan : 4 / 94 Through 9 / 95

Month :	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Sales *(Units)*	200	200	200	200	200	200	250	300	300	300	300	350	300	350	350	350	350	350
Sales *(Cumulative)*	1400	1600	1800	2000	2200	2400	2650	2950	3250	3550	3850	4200	4500	4850	5200	5550	5900	6250
Production From DK	80	80	80	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0
Production From Factory	125	125	125	208	208	208	250	250	250	292	292	292	354	354	354	269	354	354
Production Total	205	205	205	208	208	208	250	250	250	292	292	356	354	354	354	269	354	354
Production *(Cumulative)*	1511	1716	1921	2129	2337	2545	2795	3045	3295	3587	3879	4235	4589	4943	5297	5566	5920	6274
Completed Unit Inventory	111	116	121	129	137	145	145	95	45	37	29	35	89	93	97	16	20	24
Invent. receipts C.S. parts	128	128	160	192	192	224	224	256	288	320	320	320	352	352	352	352	352	352
Parts Issues to Fact./Distr. C.S.	125	128	128	208	208	208	250	250	250	292	300	300	354	360	352	275	360	352
Net Inventory Parts (C.S.)	58	58	90	74	58	74	48	54	92	120	140	160	158	150	150	227	219	219
Total Inventory C.S. plus cars	169	174	211	203	195	219	193	149	137	157	169	195	247	243	247	243	239	243
Quarter #	<----	VII	---->	<----	VIII	---->	<----	IX	---->	<----	X	---->	<----	XI	---->	<----	XII	---->

C.S. [Car Sets]

William R. Warf 8/1/92

Inventory Control System:
A small computerized Material Requirements Planning System will be installed during the factory start up phase. Data on customer reactions, orders, and purchases will be input to this computer on a daily basis. This data will be used to update the Master Production Schedule weekly, and to issue adjustments to the shipping schedule from Denmark and eventually from Domestic suppliers. The inventory level will be adjusted daily by decrementing inventory according to daily build, and also decrementing spare parts shipments. Daily entry of inventory receipts will also be required.

Inventory levels will be reported to CityCom A/S weekly or more frequently. Container shipment schedules will be updated weekly during the first year of operations (Quarters I through IV), and daily after that until regular container shipments start to decrease in month 31 (Tenth Quarter). Container shipment time is expected to average 35 days. This relatively long shipping time must be added to original equipment supplier's lead time, and requires tremendous coordination and communication between all parties. It is possible to achieve such coordination, as exemplified by NUMMI, in Fremont California, where 5 days inventory supply is achieved despite a supplier chain which stretches to Japan (Reference 1). All materials and components in transit will be tracked by the inventory system.

The Inventory Control system will also accept supplier lead time commitment information. Suppliers who add value to their inventory of Mini-el parts in step with the Mini-el Master Production schedule will receive consideration in terms of additional components sourcing, and faster payment terms.

When used in this way the Inventory Control System provides an important measurement tool to gage the performance of suppliers, distribution system, and the factory. Material Requirements Planning systems such as this have been around since the early 1960's. Many companies use them very well to control inventory levels, although few companies have mastered the ability to use them well to gage sales. Predicting sales will require the distributors to request each prospective buyer to complete a market survey questionnaire. This idea is developed more completely in the Distribution Plan.

Spare Parts Inventory:
Spare parts shipments plus information from City Com A/S will be used to develop inventory levels required to guarantee shipment of spare parts to any distributor or customer within 24 hours of order by the end of the eighth quarter of operations.

FACTORY DESIGN AND MANUFACTURING PROCESSES

The Mini-el consists of 509 parts attached together by approximately 792 fasteners. The Factory which is described in the following was designed by first designing the process by which the Mini-el's will be assembled. Consideration and study was given the factory design used at CityCom A/S, and the process implied by that factory. This section of the Manufacturing Plan will describe the Manufacturing Philosophy, the Manufacturing Process to be used, and finally the proposed Factory Design.

It is important to note the CityCom A/S factory in Denmark will continue to produce the chassis tub, and to supply this tub as a finished component to Mini-el USA. The top portion of the Mini-el is a component likely to be subcontracted in the US, since it will likely be tailored to the US market by incorporation of photo-voltaic panels or other options. Significant floor space is dedicated to manufacture of the tub at CityCom A/S. This space makes the Danish factory larger than the proposed US factory. Existing tooling for the chassis tub in Denmark also dramatically reduces the capital required to start Mini-el USA.

Manufacturing Philosophy:

Mini-el USA intends to be a world class manufacturing concern. Many companies in the US and Europe also have the same intentions and business goals, but must first modify existing operating procedures and culture. Mini-el USA has an advantage if it is set up with a lean operation from the start. World class companies are defined as those whose value adding time is 50 % of the total effort in the factory. Value adding time is defined as time which is spent actually converting the product into something which is to be sold to the customer. A complete dissertation on world class manufacturing is certainly well beyond the scope of this document, but interested readers may refer to reference 1. It is worthwhile to describe the "Seven Wastes" which constitute the bulk of non-value adding time in most companies, since the process plan which follows, and the entire Manufacturing Plan, has been written with an eye towards minimizing these wastes. These are "The Seven Wastes":

1. Over production: Making more than used or sold.
2. Waiting: Literal, waiting for information, material or equipment
3. Stocks: extra things to do or inventory, or over-production
4. Un-necessary Processing: Rework, Some Inspections, not doing it right the first time
5. Transportation (of product): un-necessary moving of product
6. Motion (people): walking to get information or material
7. Making defectives: undiscovered mistakes incorporated in product

Manufacturing Processes:

Assembly of the Mini-el has been broken down into 14 on line assembly steps, and 8 "adjacent to line" sub-assembly steps. These steps have been selected based on the type and location of parts to be assembled to produce the Mini-el. Table 3, Factory Operations Analysis, summarizes these steps, including the assembly time estimated as optimum. A 90% cost reduction curve or learning curve was used to estimate assembly time as experience with Mini-el assembly is gained. The learning curve assumption is that a time of 480 minutes (8 hours) will occur at unit 12,500 produced by the US factory. A 90% curve gives the first unit assembly time as 35.56 hours (2134 minutes). This allows times to be estimated for various unit numbers, as shown in Table 3, and as used in the Budget. Use of the learning curve also provides a method for quantifying continuous improvement in the manufacturing process.

Figure 2 provides a graphic of process time for each assembly or sub-assembly step. In this graphic each process step is depicted by an arrow of with a length relative to the specific process time. This graphic helps visualize the time required for each step, and when the step must be started to avoid waiting. Figure 2 is also useful since it provides a rough plan to draw the continuall moving assembly line, described in the Factory Design description

Each Process step is briefly described in the following. The description includes the applicable fixtures, and major components attached to the Mini-el. Fastener count includes screws, nuts, bolts, and washers.

STATION A...Chassis Rear: (On Line)
On line length: 7.25m T=3500 Units Assembly time: 57 minutes
Number of Parts: 58 Number of Fasteners: 103

At this station the Mini-el chassis tub is attached to the moving assembly line. The battery tray, roll bar, seat belts, hand brake handle, battery tray and charger tray plus some other small parts are installed. A drilling fixture is used to drill the holes for the battery box. This fixture matches tooling used by the supplier to punch holes in the battery tray. Foam strips are cut in a trim fixture and glued to the chassis.

STATION B...Chassis Electrical: (On Line)
On line length: 3.65m T=3500 Units Assembly time: 29 minutes
Number of Parts: 13 Number of Fasteners: 38

Tail lights, License and Reverse Light, Wiring Loom, and othe small fittings in the rear of the chassis are installed. Drillin jigs are used to drill the required holes.

Table 3

Factory Operations Analysis

Part count + Assembly Time By Work Station

Station ID	Description	Parts Book Reference	Qty Parts	Qty Fasteners	Optimum Est. Min.	.5K Unit Minutes	3.5K Unit Minutes	10K Unit Minutes
A	Chassis rear	[1C], [1B]	58	103	40	80	57	45
B	Chassis electrical + harness	[1C pcs {25-28,30-34,40,41}],[7]	13	38	20	40	29	23
C	Motor compart. electronics	[1C], [1B]	30	80	30	60	43	34
D	Chassis nose build	[1A] all [3 pcs 31,90,91]	31	61	30	60	43	34
S1	Rear suspension sub assy.	[6]	78	88	40	80	57	45
E	Rear suspension to chassis	[1C pcs 71-78]	9	30	10	20	14	11
S2	Front suspension sub assy.	[5]	52	69	35	70	50	39
F	Front suspension to chassis		7	16	15	30	22	17
S3	Pedals sub assy.	[4]	32	21	15	30	22	17
S4	Wheels tires sub assy.	[5],[6]	27	17	15	30	22	17
G	Inst. S3, S4, Bleed brks, Whl drag	[5],[6]	6	7	25	50	36	29
S5	Upper frame + dash	[3]	72	85	35	70	50	39
H	Inst. S5 up. frame + dash	[3]	3	8	10	20	14	11
S6	Steering sub assy.	[5]	11	18	10	20	14	11
J	Inst. S6 + up. frame chassis conn.	[5]+	1	10	10	20	14	11
S7	Seat module	[1B]	7	50	25	50	36	29
K	Inst. S7 + seats	[1B],[1C]	5	21	10	20	14	12
L	Batt., cables, chrgr cover	[1B],[1C]	22	34	15	30	22	17
S8	Upper body	[2]	25	20	30	60	43	34
M	Fit upper body		4	6	10	20	14	11
N	Wipers, final fittings	[2]	16	10	20	40	29	23
P	Test				30	60	43	34
			509	792	480	960	688	543

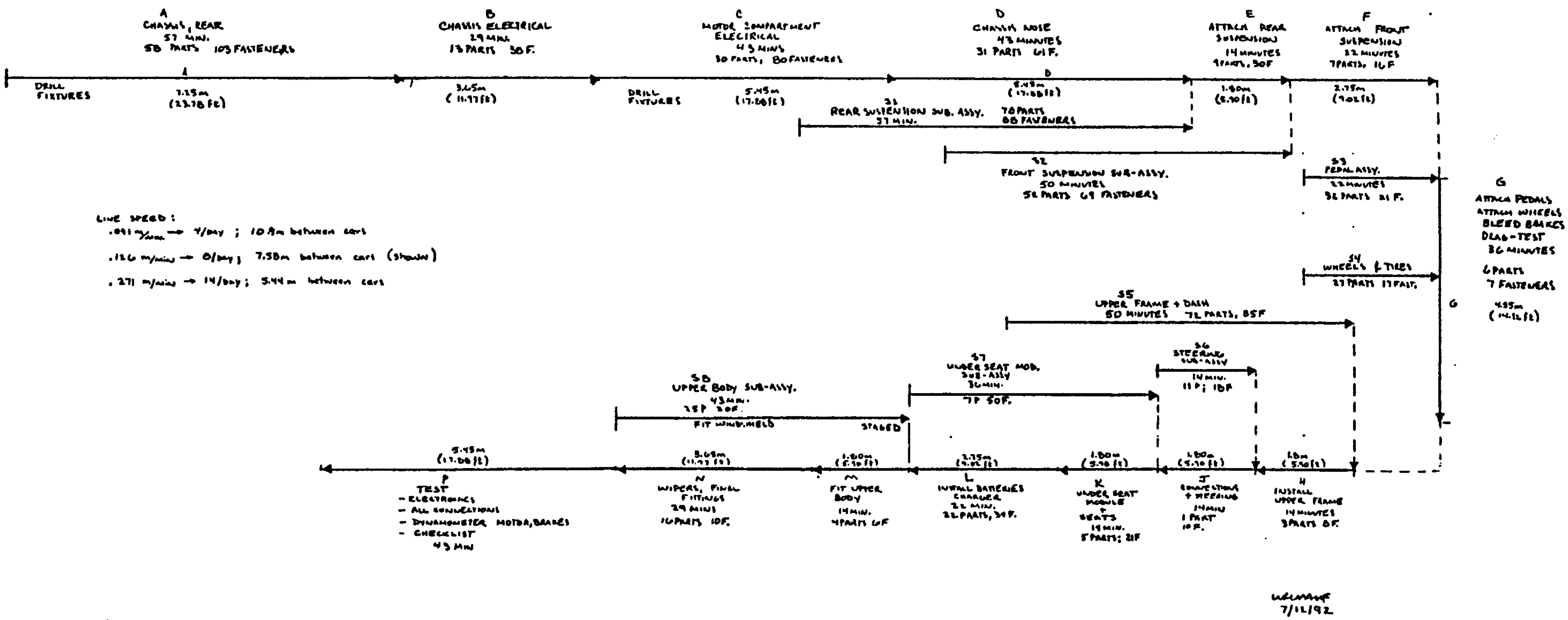
Total manufacturing time 57.3% Line, 42.7% Sub Assemblies • Cost Reduction / Learning Curve 90% T1 = 35.56 hrs.

William R. Warf 8/1/92

FIGURE 2

MINI-EL

GRAPHIC OF ASSEMBLY TIME



STATION C..Motor Compartment Electrical: (On Line)
On line length: 5.45m T=3500 Units Assembly time: 43 minutes
Number of Parts: 30 Number of Fasteners: 80

Windshield Washer, Motor Controller, Relays, Buss, Brackets, and Hydraulic lines are installed. Wiring Loom connections are made. A Drilling fixture is used to drill holes in rear bulkhead.

STATION D...Chassis Nose Build: (On Line)
On line length: 5.45m T=3500 Units Assembly time: 43 minutes
Number of Parts: 31 Number of Fasteners: 61

The grille, headlamps, sidelamps, and horn and associated components are installed. A Drilling fixture is used to drill holes in the nose section of the chassis tub. The front bumper is glued and clamped. Trim fixtures are used to trim small insulating strips in the headlight-grill area.

SUB-ASSEMBLY S1...Rear Suspension Sub-Assembly
T=3500 Units Assembly Time: 57 Minutes
Number of Parts: 78 Number of Fasteners: 88

This sub-assembly includes the axle, brake plates, motor carrier and pulleys, belt, primary drive motor, springs, and other rear suspension parts. This assembly is accomplished on a fixture which will hold the parts in the proper orientation. At least two fixtures are used for a build rate of 4 units per day. The Rear Suspension Sub-Assembly bench is located near the line so that the fixture may be removed after installation of the suspension on the chassis, and returned to the build area. Assembly tools include a special tool to tension and measure belt tightness.

STATION E...Rear Suspension, Attach to Chassis: (On Line)
On line length: 1.80m T=3500 Units Assembly time: 14 minutes
Number of Parts: 9 Number of Fasteners: 30

Sub-Assembly S1 is attached to the chassis and aligned. Shock absorbers, shims, and other small components are added.

SUB-ASSEMBLY S2...Front Suspension Sub-Assembly
T=3500 Units Assembly Time: 50 Minutes
Number of Parts: 52 Number of Fasteners: 69

The complete front suspension assembly except for wheel and tire is assembled. This assembly requires a both a fixture and a small press arrangement for assembly. The sub-assembly is removed from the fixture for installation on the chassis. The sub-assembly station is located adjacent to the main assembly line to allow installation shortly after sub-assembly completion.

STATION F...Front Suspension, Attach to Chassis: (On Line)
On line length: 2.75m T=3500 Units Assembly time: 22 minutes
Number of Parts: 7 Number of Fasteners: 16

At this station Sub-Assembly S2 is installed on the Mini-el chassis tub.

SUB-ASSEMBLY S3...Pedals Sub-Assembly
T=3500 Units Assembly Time: 22 Minutes
Number of Parts: 32 Number of Fasteners: 21

This sub-assembly is accomplished at a small bench near the main line. The Pedals Sub-Assembly is comprised of the master cylinder, brake fluid reservoir, brake and throttle pedals, and throttle rheostat.

SUB-ASSEMBLY S4...Wheels and Tires Sub-Assembly
T=3500 Units Assembly Time: 22 Minutes
Number of Parts: 27 Number of Fasteners: 17

In this sub-assembly tires are mounted on the wheels, inflated, an balanced. Steel brake drums integral with wheel are cleaned t assure freedom from corrosion inhibiting preservatives.

STATION G...Pedals, Wheels & Tire Assemblies to Chassis: (On Line)
On line length: 4.55m T=3500 Units Assembly time: 36 minutes
Number of Parts: 6 Number of Fasteners: 7

Sub-Assemblies S3 & S4 are installed. Hand brake cables are attached and the hand brake adjusted. The brake fluid reservoir is filled and the brakes bled utilizing a power bleeder. Wheel drag is checked to assure correct assembly, using a special fixture.

SUB-ASSEMBLY S5...Upper Frame + Dash Sub-Assembly
T=3500 Units Assembly Time: 50 Minutes
Number of Parts: 72 Number of Fasteners: 85

This Sub-Assembly consists of all the parts attached to the aluminum frame which hinges and supports the body. A fixture which matches body mounting points is used. This fixture also may allow positioning of the body for access to all surfaces.

STATION H...Install Upper Frame: (On Line)
On line length: 1.80m T=3500 Units Assembly time: 14 minutes
Number of Parts: 3 Number of Fasteners: 8

Sub-assembly S5 is installed on the Mini-el chassis tub.

SUB-ASSEMBLY S6...Steering Sub-Assembly
T=3500 Units Assembly Time: 14 Minutes
Number of Parts: 11   Number of Fasteners: 18

This sub-assembly is accomplished on a bench remote from the installation point on the line. Sub-assemblies are rolled towards the line on the roller conveyor in re-useable boxes, which are returned to the station after steering installation. The sub-assembly consists of the steering wheel, sliding steering wheel shaft, and the Hooke joint coupling.

STATION J...Steering Installation: (On Line)
On line length: 1.80m T=3500 Units Assembly time: 14 minutes
Number of Parts: 1   Number of Fasteners: 10

The Steering Sub-assembly is installed.

SUB-ASSEMBLY S7...Under Seat Panel
T=3500 Units Assembly Time: 36 Minutes
Number of Parts: 7   Number of Fasteners: 50

This sub-assembly requires mounting of the under-seat electronic control boards, including the battery capacity-discharge counter, battery charger, DC-DC converter, and cooling fan to the aluminum panel which supports the seat. These sub-assemblies are fed to the line in a manner similar to S6, in re-useable boxes.

STATION K...Seat Installation: (On Line)
On line length: 1.80m T=3500 Units Assembly time: 14 minutes
Number of Parts: 5   Number of Fasteners: 21

The Seats plus sub-assembly S7 are installed.

STATION L...Install Batteries: (On Line)
On line length: 2.75m T=3500 Units Assembly time: 22 minutes
Number of Parts: 22   Number of Fasteners: 34

The Batteries and Cables are installed.

SUB-ASSEMBLY S8...Upper Body Sub-Assembly
T=3500 Units Assembly Time: 43 Minutes
Number of Parts: 25   Number of Fasteners: 20

The painted Upper Body plastic part is assembled on a fixture. The windshield is installed. Trim parts, latches and other components are fitted.

STATION M...Fit Upper Body: (On Line)
On line length: 1.80m T=3500 Units Assembly time: 14 minutes
Number of Parts: 4 Number of Fasteners: 6

Sub-assembly S8 is attached to the upper frame already installed on the Mini-el.

STATION N...Wipers, Final Fittings: (On Line)
On line length: 3.65m T=3500 Units Assembly time: 29 minutes
Number of Parts: 16 Number of Fasteners: 10

Final connections between the Upper Body fittings and the Upper Frame are made. The Mini-el is completely assembled.

STATION P...Unload from Line plus Final Test:
On line length: 5.45m min. T=3500 Units Assembly time: 43 minutes
Number of Parts: 16 Number of Fasteners: 10

Tests include dynamometer tests of the motor and drive train efficiency, brakes, function of all electrical devices. A burn-in test is accomplished on the electrical control panels. Correct functioning of the battery charger, battery discharge meter is verified. All tests utilize a data collection system to record actual values by vehicle serial number. These Tests verify functioning is within narrow process control limits.

Factory Design:

The central concern of the factory design is to maximize throughput of component parts converted to finished Mini-el's of the highest quality with no rework. This discussion of the factory design will focus on how the assemblies are produced with zero defects, and how material is moved through the factory to produce Mini-el's.

The actual assembly area consists of about 10,000 square feet of work space, which encompasses a continuously moving overhead conveyor. The assembly team works in close proximity to each other, maximizing between station communication and flexibility in their work. If a problem occurs the line is stopped until the problem is solved by addressing the cause. Any assembly team member may stop the line if a quality problem or supply problem which would require rework at a later point is encountered. As will be discussed below in the Personnel and Quality Assurance section, the Mini-el USA factory will have no separate Quality Control department. Achieving quality is not the responsibility of someone else, or some separate department. All Mini-el USA employees will receive training in problem solving emphasizing cause determination. All employees will receive two months "on line" of training in all facets of Mini-el construction, so that they will recognize a problem when it occurs.

The Factory Design is shown in Figure 3. A full size blue print of this drawing is attached to the back cover of this Manufacturing Plan. The Mini-el Facility Layout focuses on the floor space required for manufacturing Mini-el's, not for storing finished assemblies. The basic floor space required is about 20,000 square feet. Additional space which is not shown will be needed for the Factory Service Center, R&D, Sales, and other support functions, as well as staging and shipping finished Mini-el's. The Manufacturing Budget will utilize 30,000 square feet as a cost basis, since a facility between 25,000 and 30,000 square feet is ultimately required.

The Mini-el factory will be operated from leased real estate for the first five years to minimize capital costs during this start-up period. For this reason it would be premature to completely design facilities other than the basic manufacturing and component inventory space. After the actual site is located, the layout representing the manufacturing facility as shown, plus other support facilities will be fit into the actual site.

A description of the operation of the Mini-el facility follows.

Assembly Line Operation:

The continuously moving assembly line utilizing an overhead conveyor is extremely flexible. Both the density or spacing along the line of Mini-el's being assembled and the line speed are varied to achieve the build rate. 57% of the total assembly effort is expended on the moving assembly line. The remaining 43% of the effort is achieved in sub-assembly stations. The relationship of spacing of units on the line and line speed is illustrated by the following examples.

Quarter VII: 17.07 hours per unit = 1024 minutes per unit
The "on line" time is 0.57*1024= 586 minutes
At 6 units per day, 480 minutes/6 gives the 64 meter long line yielding one unit every 80 minutes...
586/80 gives 7.33 cars on line,
64/7.33= one unit every 8.73 meters
The line speed is 8.73 meters/80 minutes= 0.11 meters/minute

This same calculation, utilizing assembly times which coincide with the appropriate build rate period results in the following:

Daily Build Rate	6	10	14	17
Car every __ meters	8.73	6	5.39	4.44
Line speed meters/min.	0.11	0.13	0.16	0.16

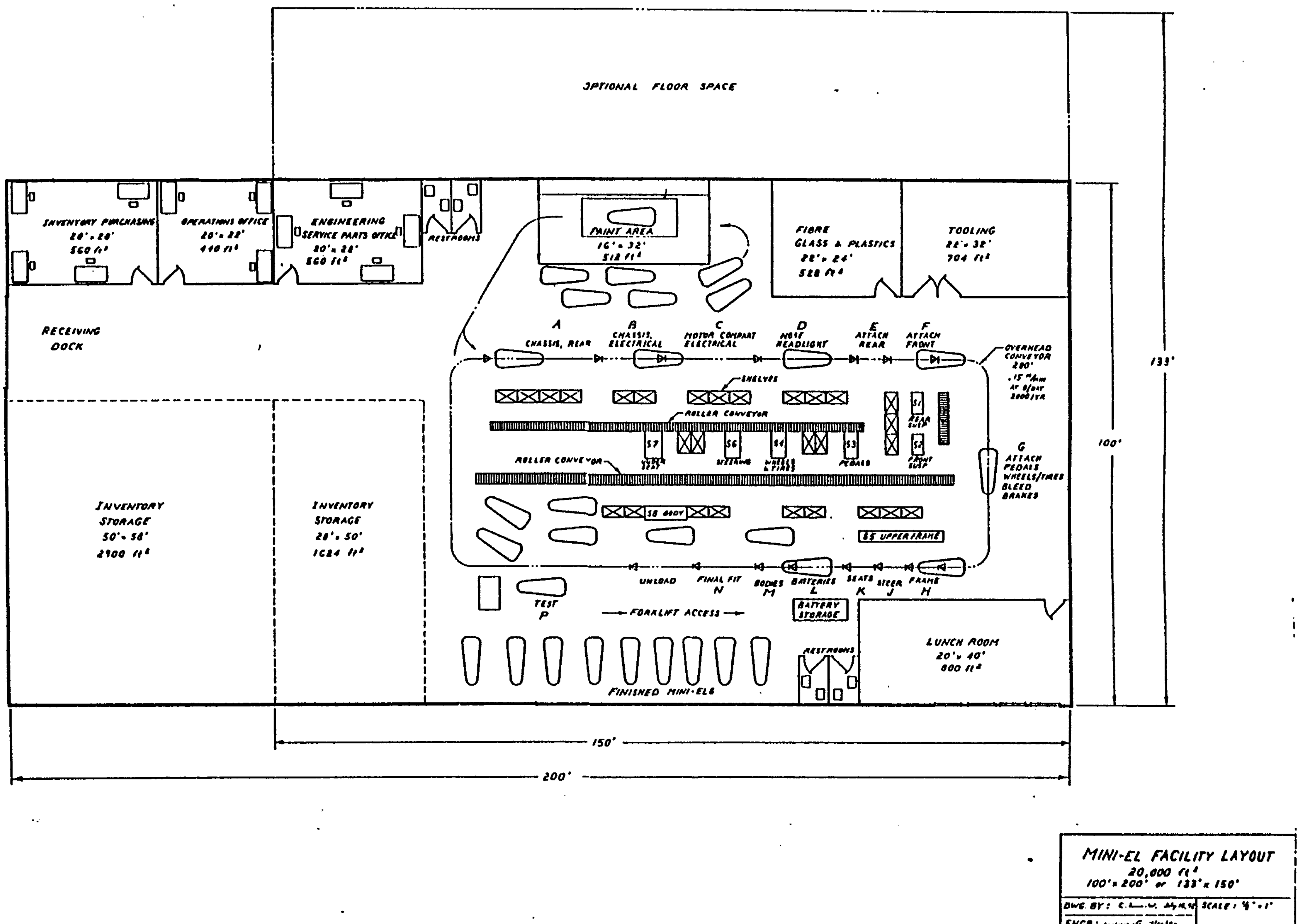

OPTIONAL FLOOR SPACE
INVENTORY PURCHASING
28' x 20'
560 ft²
OPERATIONS OFFICE
20' x 22'
440 ft²
ENGINEERING
SERVICE PARTS OFFICE
20' x 28'
560 ft²
RESTROOMS
PAINT AREA
16' x 32'
512 ft²
FIBRE
GLASS & PLASTICS
22' x 24'
528 ft²
TOOLING
22' x 32'
704 ft²
RECEIVING
DOCK
A
CHASSIS, REAR
B
CHASSIS, ELECTRICAL
C
MOTOR COMPART ELECTRICAL
D
NOSE HEADLIGHT
E
ATTACH REAR
F
ATTACH FRONT
OVERHEAD CONVEYOR
280'
SHELVES
ROLLER CONVEYOR
S1
REAR SUSP
S2
FRONT SUSP
S3
PEDALS
S4
WHEELS & TIRES
S6
STEERING
S7
SEAT
ROLLER CONVEYOR
G
ATTACH
PEDALS
WHEELS/TIRES
BLEED
BRAKES
S8 BODY
S5 UPPER FRAME
INVENTORY
STORAGE
50' x 58'
2900 ft²
INVENTORY
STORAGE
28' x 50'
1624 ft²
UNLOAD
FINAL FIT
N
BODIES
M
BATTERIES
L
SEATS
K
STEER
J
FRAME
H
TEST
P
FORKLIFT ACCESS
BATTERY
STORAGE
RESTROOMS
LUNCH ROOM
20' x 40'
800 ft²
FINISHED MINI-ELS
133'
100'
150'
200'
MINI-EL FACILITY LAYOUT
20,000 ft²
100' x 200' or 133' x 150'

FIGURE 3

The conveyor will have the capability of line speeds ranging from 0.05 to 0.3 meters per minute. If Mini-el's are loaded on the line with one meter between each car, the maximum density is one Mini-el every 3.74 meters. The maximum shift capacity of this assembly line is estimated at about 30 units per day.

The off line operations were described in the process description presented above. These sub-assemblies are accomplished in step with the actual production of Mini-el's.

Inventory is stored along the assembly line and at sub-assembly stations in boxes specific to the work station. When additional parts are needed on line one of the boxes in the group is sent back to the inventory area using the roller conveyors which extend down the middle of the assembly area. The inventory personnel refill these manual "pick requests" and send the filled boxes back to the appropriate station. The assemblers work together to move these parts and empty containers along the roller conveyors, allowing the inventory-personnel to feed the front end of the conveyors.

Since the assemblers are trained in all assembly steps, as previously mentioned, they are able to help out in other assembly stations as they complete their assembly or sub-assembly steps. This helps to keep the line moving at a uniform rate, and facilitates team work. Early in the factory start-up, there are fewer direct labor personnel than assembly stations. During this time some assemblers will be required to man two stations, such as the S7 seat module and the S6 steering assembly. The proximity of short duration assembly line stations, as shown in Figure 3 facilitates this capability.

Included near the assembly line is a paint booth, which will be constructed in accordance with all California EPA and other applicable requirements. This facility allows painting Mini-el's to match the customer or distributor orders. Mini-el Chassis Tubs and Upper Bodies are loaded into roll-able cart-fixtures and staged before the paint area. After painting, the Chassis Tub is loaded onto the moving assembly line, and the upper body is staged near the S8 Upper Body sub-assembly station.

The Mini-el USA facility also includes a plastics area and a tooling shop. The intent of the tooling area is the ability to construct and maintain virtually all tooling and fixtures in house. This will assure that improvements needed by assembly personnel can be expeditiously incorporated. The plastics area allows for special modifications to Mini-el's, and R&D tooling manufacture and component prove out support to the factory.

In the inventory area component parts are stored according to their destination on the line. Shelves will be marked, as will the manual "pick request" boxes to aide in storage operations as containers of parts are unloaded. City Com A/S part numbers will be used through-out. Various inventory areas are cycle counted

frequently to maintain an accurate inventory in the computer system. Fasteners needed on line may be "kitted" in assembly or sub-assembly groups by fastener suppliers to facilitate minimum handling.

Factory and Capital Equipment:

The equipment needed to set up the Mini-el USA factory is shown in Table 4. This equipment list provides the basis of the equipment capitalized and depreciated in the budget section of this Manufacturing Plan. Some items on this list will be expensed instead of capitalized, however this table provides a good estimate of equipment needed. Much of the required equipment will be purchased used.

It is also noted that the budget includes provisions for manufacturing additional tools and fixtures as the build rate is incremented. Also, it is noted that all of the Capital budget need not be expended in quarter V, even though this is implied by the budget section.

Budget:

The needed personnel and capital required to start up and operat the Mini-el USA factory are presented in summary form in Tables 5,6, & 7. The calculations, methods, and assumptions used to construct these tables are discussed in this section of the Manufacturing Plan. Table 7 provides a sample Pro-Forma Profit and Loss Statement through the gross margin line, as a convenient way of expressing the budget. These tables match the information provided in the Schedule, Figure 1; The Inventory Plan, Tables 1 & 2; and the Operations Analysis, Table 3.

Personnel Requirements:

Personnel requirements are estimated by applying a 90% cost reduction curve to the estimated assembly time. As previously stated in the Process Description section, the assembly time is estimated as 8 hours at unit 12,500, which gives a first unit assembly time of 35.56 hours per unit. Since the factory does not start producing Mini-el's in earnest until the VI quarter of Mini-el USA operations, this analysis takes into account only Quarters VI through IX (1994), and X through XIII (1995). Also shown are estimated values for 1996 & 1997.

Table 5 summarizes the personnel required to operate the Mini-el factory. The total number of direct labor employees required is calculated by finding the mid point unit for the period, finding the cost reduction curve factor from the learning curve (Appendi 1), and calculation of the total period hours. For example t Quarter VIII period hours are 624 units produced * 0.420 * 35.5 = 9320 hours. The total hours needed in the period are divided by the number of clock hours in the period (500 hours per quarter) to give the calculated number of employees. 9320/500 = 18.64.

Table 4
Capital Equipment

Equipment	
Line conveyor 280'	$28,000
Roller conveyor 160'	$7,360
Small forklift truck, used	$10,000
Material handling equip.	$5,000
24 Shelves, line @ $250 each	$6,000
20 work tables	$5,000
Compressor 170 psi 100	$6,000
Paint equipment	$3,000
Paint booth	$10,000
Air plumbing	$5,000
Final test:	
...Data collection	$2,000
...Dyno	$20,000
...Computer	$2,000
...Electronics	$2,000
Assembly tools:	
...Air drills, 12	$1,800
...Air wrenches	$2,500
...Other	$2,000
...Battery chargers	$500
...Measuring tools	$5,000
...Small lathe	$8,000
...Bridgeport mill	$18,000
...Tooling, mill & lathe	$9,000
...Welding equip.	$7,500
...Power bleeder	$400
...Small tooling press	$1,000
...Sheet metal tools	$3,000
...Drill press	$1,500
Inventory area shelves	$10,000
Subtotal	$181,560
Misc. tools	$20,000
Equipment total	$201,560

Other Equipment	
Computer systems	$25,000
...Inventory software	$15,000
...Office software	$5,000
...Office equipment	$6,000
...Drawing board & equipment	$500
Hazardous Material Program	$5,000
Other state filings	$2,000
Packaging materials	
Fixture design	
Phone system	$1,500
Copy equipment	$3,000
Fax	$800
Other Equipment Total	$60,000

Tools		
Fixtures list:		
...S1 Rear suspension (2)		$3,000
...S2 Front suspension		$2,500
...S3 Pedals		$500
...S4 Tire mount / balance		$600
...S5 Upper frame / dash		$3,000
...S6 Steering		$0
...S7 Seat		$0
...S8 Upper body		$3,000
Drilling fixtures		$5,000
Foam strip cutters		$2,000
Wheel drag		$500
Paint fixture body, 5	[ib]	$7,500
Paint fixture chassis, 5	[ib]	$7,500
Tools total		$35,100

Tools & Equipment Total	$296,660
Start up tool equip. & supplies Contingency, approx. 25% of total	$74,165
Total	$370,825

[ib] Increment with build

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TABLE 5 : PERSONNEL REQUIREMENTS

YEAR	1994				1995				1996	1997
QUARTER	VI	VII	VIII	IX	X	XI	XII	XIII	–	–
U.S. PRODUCTION, PERIOD	134	375	624	750	876	1062	977	1100	5000	6000
DAILY	2.14	6	10	12	14	17	16	17	20	24
U.S. PRODUCTION CUM	138	513	1137	1887	2763	3825	4802	5902	10902	16902
UNIT Nº MIDPOINT	50	325	825	1512	2325	3294	4314	5352	8402	13902
FACTOR-COST RED. CURVE	0.690	0.480	0.420	0.365	0.335	0.315	0.300	0.285	0.245	0.220
PERIOD HOURS	3287	6400	9320	9734	10435	11895	10422	11148	43550	47400
CALC'D EMPLOYEES	6.58	12.8	18.64	19.47	20.87	23.79	20.85	22.30	21.78	23.7
ACTUAL DIRECT EMP.	10	16	21	23	24	27	26	26	25	27
MAT'L PLAN+PURCH	1	1	2	3	3	3	3	4	4	4
INVENTORY/INSPECTION	2	2	3	3	3	3	3	3	4	4
TOOL ROOM/MAINTENANCE	1	1	1	1	1	1	1	2	2	2
SHOP SUPERVISION	1	1	1	1	1	1	1	1	1	1
ENGINEERING, R&D	1	2	2	2	2	2	4	4	4	4
FIELD SERVICE / SALES MARKETING	1	2	2	3	3	3	3	4	4	4
CLERICAL	1	1	1	1	2	2	2	2	2	2
ACCOUNTING/FINANCE	1	1	1	1	2	2	2	2	2	2
DIRECTOR	1	1	1	1	1	1	1	1	1	1
TOTAL INDIRECT EMPLOYEES	10	12	14	16	18	18	20	23	24	24
TOTAL EMPLOYEES	20	28	35	3[illegible]	42	45	46	49	49	51

Two or three employees to account for shipping and painting are added and the value rounded up to give a total number of employees, 21 in this example.

Table 5 also provides a conservative estimate of the number of indirect employees required to operate the facility. This estimate is based on the activities and processes to be accomplished in the period, as discussed throughout this manufacturing plan.

Material Costs:
Table 6 presents a calculation of the material cost for production of the Mini-el. This calculation is based on information received from City Com A/S, and on research by the author. Information is provided only for US production of Mini-el's. Imported Mini-el's will be entered in the budget at a cost of $5200 per unit, which is City Com's price to distributors for finished Mini-el's.

The US factory material cost is broken down into Body Cost, Royalty, Batteries, Balance of Components, and Freight. Batteries, components, and freight costs are calculated using the 95% cost reduction curve from Appendix 1. Table 6 provides a total material cost per unit by Quarter number from Quarter VI through XIII, and for 1996 & 1997.

Assembly time only cost derived by dividing period hours by number of units in Table 5 is also presented in Table 6.

Mini-el USA Factory Plan Budget:
This section will describe the Budget information provided in Table 7, as well as the assumptions and methods utilized to develop this budget. Table 7 shows a $986,000 Gross margin from sales of Mini-el's assembled in Denmark in the first year of operations (Quarters I through IV). This should result in a substantial budget figure to be used to set up the Mini-el facility and purchase initial inventory, as discussed in the Financial Plan. A detailed discussion of the Factory Plan Budget follows.

Sales are calculated based on unit prices shown at the bottom of Table 7, following the sales forecast already presented. Service parts sales match the Inventory Plan, at a 100% mark-up based on Car Sets, for convenience.

Material costs are calculated using $5400/unit for imported units in quantities that match the inventory plan. Material costs for US production are calculated for quantities from the inventory plan, using unit costs developed in Table 6.

Direct Labor and Indirect Labor costs use the number of personnel presented in Table 5, multiplied by 500 hours per quarter or 2000 hours per year. A labor rate of $16.00 per hour is used through 1994, $17.00 per hour in 1995, and $17.50 per hour in 1996 and 1997. Please note the plan is in 1992 dollars and has not been escalated. These rates reflect raises for longer term employees.

TABLE 6

UNIT MATERIAL COST / LABOR HOURS

YEAR	1994				1995				1996	1997
QUARTER	VI	VII	VIII	IX	X	XI	XII	XIII		
BODY COST	1200	1200	1200	1200	900	900	900	900	900	900
ROYALTY COST	200	200	200	200	200	200	200	200	200	200
BATTERIES COST	240	210	198	192	186	180	177	174	168	159
MIDPOINT UNIT	50	325	825	1512	2325	3294	4314	5352	8402	13902
COST REDUCTION CURVE FACTOR	.80	.70	.66	.64	.62	.60	.59	.58	.56	.53
BALANCE OF COMPONENTS FACTOR x 3400.00	2720	2380	2244	2176	2108	2040	2006	1972	1904	1802
FREIGHT	250	218	206	200	194	187	184	181	175	165
TOTAL MATERIAL COST	4610	4208	4048	3968	3588	3507	3467	3427	3347	3226
LABOR HOURS/UNIT ASSEMBLY ONLY	24.54	17.07	14.94	12.98	11.91	11.20	10.67	10.13	8.71	7.90

Table 7

Mini-El USA Factory Plan Budget

All $ Values in 1,000's

Year	<- 1993		--->	<-	1994		->	<-	1995		->	1996	1997
Quarter	I & II	III & IV	V	VI	VII	VIII	IX	X	XI	XII	XIII		
Sales	$1,750	$2,231	$1,575	$2,800	$4,050	$4,050	$5,525	$6,175	$6,300	$6,615	$6,930	$31,250	$37,500
Sales, Svs parts	$50	$100	$50	$20	$60	$50	$50	$60	$60	$120	$120	$500	$500
Total Sales	$1,800	$2,331	$1,625	$2,820	$4,110	$4,100	$5,575	$6,235	$6,360	$6,735	$7,050	$31,750	$38,000
Direct Materials :													
Finished Units	$1,350	$1,755	$1,193	$1,436	$1,215	$654		$333					
Components	$0	$0	$19	$618	$1,578	$1,939	$3,373	$3,179	$3,507	$3,640	$3,770	$16,735	$19,356
Direct Labor	$0	$0	$16	$80	$128	$168	$184	$204	$230	$221	$221	$875	$945
Indirect Labor	$0	$0	$32	$32	$32	$48	$56	$60	$60	$60	$77	$350	$350
Supervision	$0	$0	$10	$10	$10	$10	$10	$10	$10	$10	$10	$50	$50
Total Assembly Personnel	$0	$0	$58	$122	$170	$226	$250	$274	$300	$291	$308	$1,275	$1,345
Benefits	$0	$0	$23	$49	$68	$91	$100	$110	$120	$117	$123	$510	$538
Utilities	$0	$0	$2	$5	$6	$10	$10	$11	$12	$12	$12	$47	$52
Depreciation	$0	$0	$15	$15	$15	$15	$15	$15	$15	$15	$15	$60	$60
Facility Lease	$10	$10	$22	$22	$22	$22	$22	$28	$28	$28	$28	$120	$120
Equipment Leases	$0	$0	$5	$5	$5	$5	$5	$10	$10	$10	$10	$40	$40
Insurance	$2	$2	$36	$36	$36	$36	$36	$40	$40	$40	$40	$160	$160
Factory Supplies	$10	$6	$30	$20	$20	$40	$40	$40	$40	$40	$40	$160	$160
Outside Services	$0	$0	$100	$10	$10	$10	$10	$20	$20	$20	$20	$80	$80
Shipping	$0	$0	$1	$15	$38	$62	$75	$88	$80	$80	$80	$400	$480
Property Taxes	$0	$0	$2	$2	$2	$2	$2	$2	$2	$2	$2	$8	$8
Other (Contingency)	$0	$0	$150	$150	$150	$150	$150	$150	$250	$250	$250	$500	$500
Total Factory & Material Costs	$1,372	$1,773	$1,656	$2,505	$3,335	$3,257	$4,088	$4,300	$4,424	$4,545	$4,698	$20,095	$22,899
Gross Margin	$428	$558	<$31>	$315	$760	$843	$1,487	$1,935	$1,936	$2,190	$2,352	$11,654	$15,101
% Sales	24%	32%	<2%>	11%	18%	21%	27%	31%	30%	33%	33%	37%	40%
Units Sold	250	325	225	400	600	600	850	950	1,000	1,050	1,100	5,000	6,000
Avg. Unit Price	$7,000	$7,000	$7,000	$7,000	$6,750	$6,750	$6,500	$6,500	$6,300	$6,300	$6,300	$6,250	$6,250

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Indirect Labor employees include Material Planning and Purchasing, Inventory and Inspection, Tool Room and Maintenance. Shop Supervision cost is also shown in Table 7. The balance of the personnel requirements shown in Table 5 will be utilized in the "Other Operating Expenses" section of the Pro-Forma Profit and Loss Statement presented in the Financial Plan, and are therefore not included in Table 7.

Employee Benefit costs are calculated based on 40% of the Wages and Salaries costs.

Utilities are calculated based on $0.10 per kiloWatt hour based on expected usage, and based on 500 hours per quarter.

The depreciation line reflects a capitalized amount of $420,000, based on the estimate computed in Table 4, and amortized over 7 years using a straight line method.

The Facility Lease line reflects a small facility lease for the Factory Service center in the first year of operation. The factory lease commences in Quarter V, and is calculated based on 30,000 square feet at $0.24 per square foot per month. It is noted that the lease amount is conservatively increased in 1995.

Equipment Leases, Insurance, Factory Supplies, Outside Services, and Property Tax costs are assumptions.

Shipping costs are estimated by multiplying the unit production in the period by $100 per unit.

<u>Personnel and Quality Assurance:</u>
The personnel and quality assurance functions will be managed by the five key Salaried employees, hereinafter referred to as the "Staff". These positions in Mini-el USA include the Director, the Field Service and Marketing Manager, the Chief Engineer, the Finance Manager, and the Shop Supervisor. This section of the Manufacturing Plan presents a brief management plan to illustrate how important functions will be completed with a limited staff. This represents an abbreviated Management Plan.

Personnel records and requirements will be maintained by the Staff supported by clerical individual(s). Part time help or consultants may be employed to help set up basic systems and to document State mandated programs, such as Affirmative Action, ADA, Emergency Action Plans, and Hazardous Materials Programs. The above programs will in general be written and approved by the Staff.

The Quality function will be the responsibity of the Director With the help of his staff, he will assure that all employee receive regular rotations through the various stations and functions associated with Mini-el production.

As a part of the Quality function, the Director will assure training is accomplished, with preference to problem solving and electric vehicle technical issues. The job rotation mentioned above will include all positions except the Staff and the Materials and Purchasing positions, which require dedicated employees. Both the Tooling/Maintenance and Clerical positions require specific skills which may not be shared by all employees, and thus may be subject to limited rotation. Rotation through positions as the company matures may become a form of reward for employees who excel. The rotation through positions will include field service calls or EV shows and fairs supported by the Field Service and Marketing Manager. This type of rotation will assure employees stay in touch with customers, and help assure quality.

The only inspection functioned to be accomplished will have to do with the acceptance of incoming inventory. This is the reason Inventory and Inspection functions occupy one line on the Mini-el USA Factory Plan and Budget, presented in Tables 5 & 7. When ever possible a few pieces from each lot of parts will be immediately checked on assembly line tooling to verify the incoming parts features are correct. Inspection problems or other problems discovered later will be tracked in the Inventory Control computer, to aid in supplier performance evaluations.

Quality will also be discussed frequently in meetings lead by a Staff member. Meeting attendance will be limited to about 10 employees, and will mix training and discussions of Quality and Throughput or Production issues. Mini-el USA will be a fun place to work, as due to the rotation in stations, the chemistry of these groups will be constantly changing.

All employees are charged with making a contribution to same goals, Quality first, and then Schedule. All employees will be responsible for thinking, as well as production. All employees will take a test and be scored prior to hiring, to provide a defensible non-discriminatory basis for hiring the best. The entry level position at Mini-el USA will be called Customer Service Technician.

Employees will also be frequently briefed on the status of the companies performance compared to plan. Wage increases are part of the plan, and all employees deserve to know what the plan is. The intent of Mini-el USA will be to make long term employees of people hired, that is we will have low turn-over to protect our employee investment. Extreme care will be excersized during the start-up to avoid an excess inventory of employees, just as excess material inventory is avoided.

R&D and Engineering:

This functional group will have three primary responsibilities, which are change control & documentation, Research and Development, and Field Service. Since these are important to the long term success of Mini-el USA, they are briefly discussed here as a means of justifying the positions in Table 5.

Change Control & Documentation
The Mini-el produced in the USA will be absolutely identical to the model produced in Denmark for at least the first two years. Engineering is responsible for coordination of changes initiated by the Danish or US factory with the Material Planner, to assure the latest changes are reflected in the bill of material saved for each serial number. Engineering will also be responsible for test checklists, and statistical analysis of in process measurements.

R&D
Engineering and R&D positions will play a major role in Field Service and Sales, especially in the early years. Feed back from distributors will be reviewed for technical issues, and improvements in the Mini-el will be planned. A specification for the future model to be produced by Mini-el will be developed.

Drawings may have to be produced for tooling or product improvements. The budget produced for this plan suggests cost savings improvements, reducing the number and cost of parts will be a substantial benefit to Mini-el USA.

Field Service
The Chief Engineer will be responsible for oversight of Distributor Training, and evaluation of field problems. A customer call process will also be implemented in which product evaluations with input from some Mini-el customers will be accomplished.

List of References:

1) The Machine that Changed the World; Womack, Jones, and Roos, 1990, ISBN: 0-89256-350-8

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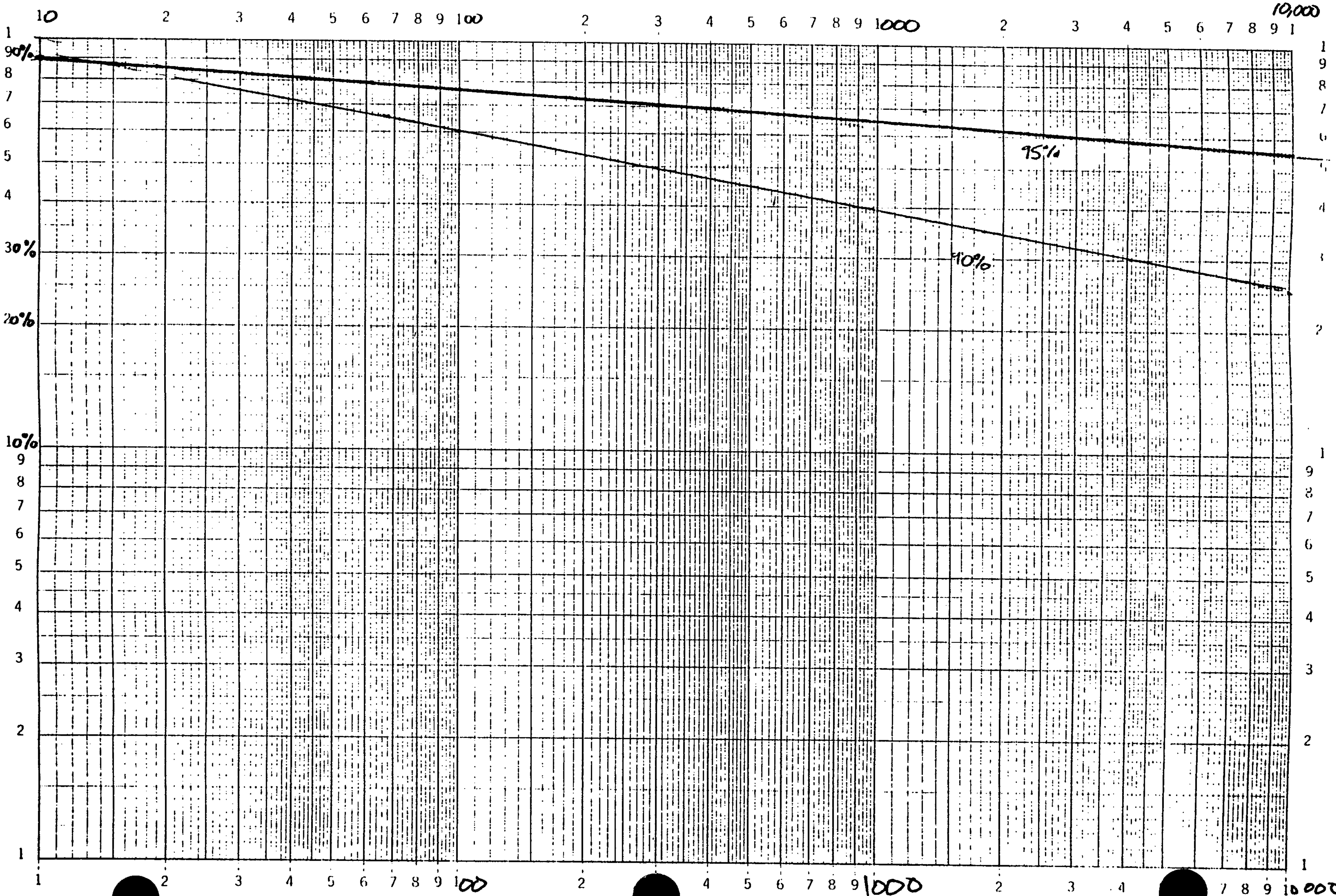

APPENDIX 1.

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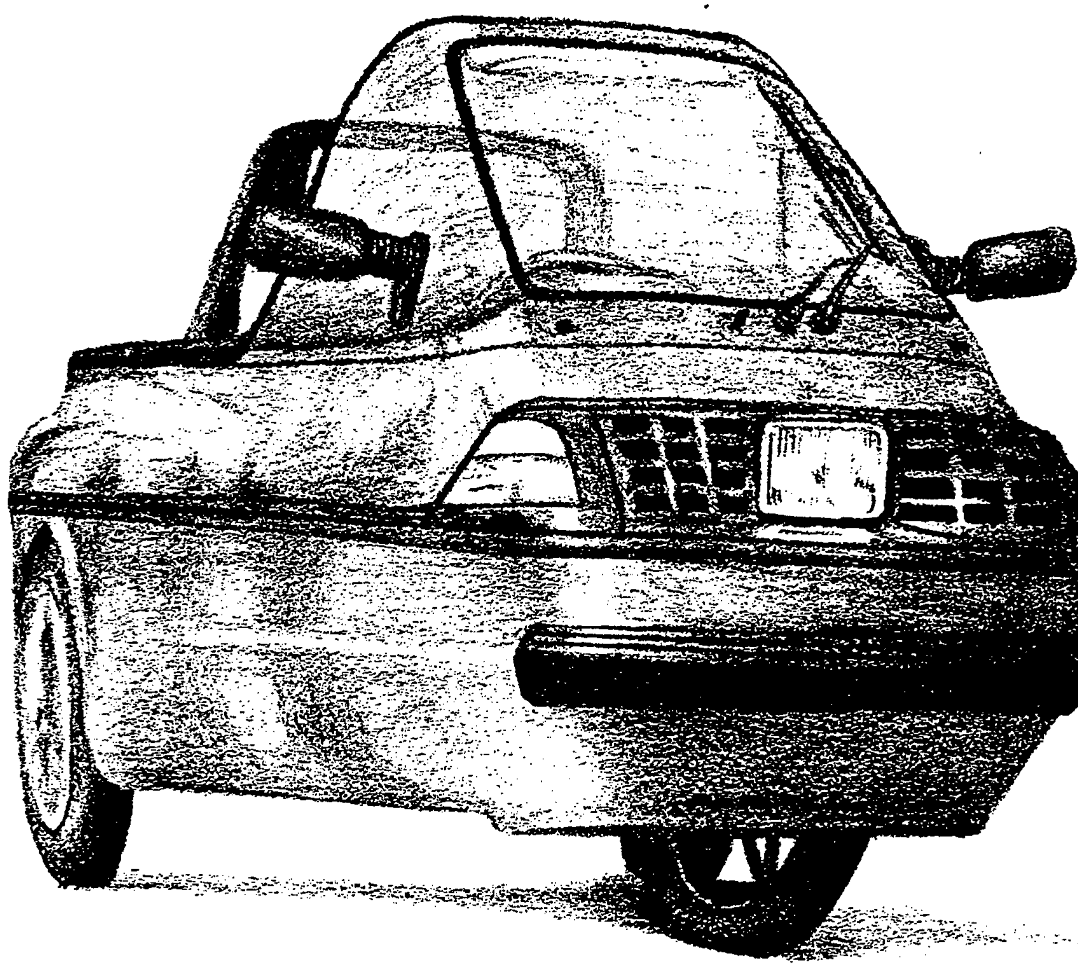
Mini - el

U.S. MARKET ESTIMATE

Prepared by
William R. Warf P.E.

10 August, 1992



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Executive Summary: Mini-el US Market Estimate

This Market Estimate provides a forecast of Mini-el sales through 1998. The estimate is broken down into annual sales in specific target markets which represent 44% of the US light vehicle market. These target markets also provide the most likely areas to achieve significant Mini-el sales, because of conditions favorable to Electric Vehicle use, population density, and market depth. The target markets are primarily on the East and West Coasts of the United States.

The Mini-el can achieve annual US sales averaging 2300 to 3000 units per year for the first six years of business operations. Sales of 4100 units are predicted in 1995, or between 5 and 10% of the projected US Electric Vehicle (EV) market. Minimum and maximum sales quantities are calculated. In both minimum and maximum cases, sales are conservatively assumed to ramp up from 1993 through 1998, as the distribution system is developed and consumer confidence is gained. Because of the lack of comparable products in the US, sales quantities in 1993 and 94 exceed sales projected based on technical issues.

This Market Estimate was prepared by looking at the light vehicle market from a continental region perspective, and then by focusing on finer segments of the most probable markets, to arrive at an estimate of the US Electric Vehicle market. The target markets are primarily States which either have adopted or plan to adopt minimum sales requirements for Zero Emission Vehicles for air quality reasons. This rationale should not imply that all marketing and sales effort for the Mini-el be applied exclusively to the target markets identified, even though these are the best places to start. Market coverage can be expanded as customer surveys and market research reveal additional targets.

The effect of Minimum Sales Requirements is to stimulate the US market, creating considerably more activity and consumer awareness than would have occurred without these rules. The US market will catch up very quickly with the European market, in which small, well developed electric vehicles are currently more numerous. Much of the development effort in the US has centered on Vans, which occupy the opposite end of the Electric Vehicle product spectrum in terms of weight and cost.

The estimates of market share take into account Mini-el capabilities by comparison with other transportation products in the same price range, and by considering expected EV capabilities and consumer needs. On the basis of speed and safety needs and perceptions, the Mini-el should capture 5% of the EV market. A market share of 10% or more based on range is predicted. An effort is made to take into account non-technical issues, as many EV's will be purchased for political and social reasons.

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List of Tables and Graphs

Purpose:

The purpose of this market estimate is to determine both the minimum and maximum probable annual Mini-el sales, in order to design a profitable factory. The factory must achieve a minimum profitable production level and have a maximum capacity to satisfy the probable market needs.

Scope and Method Description:

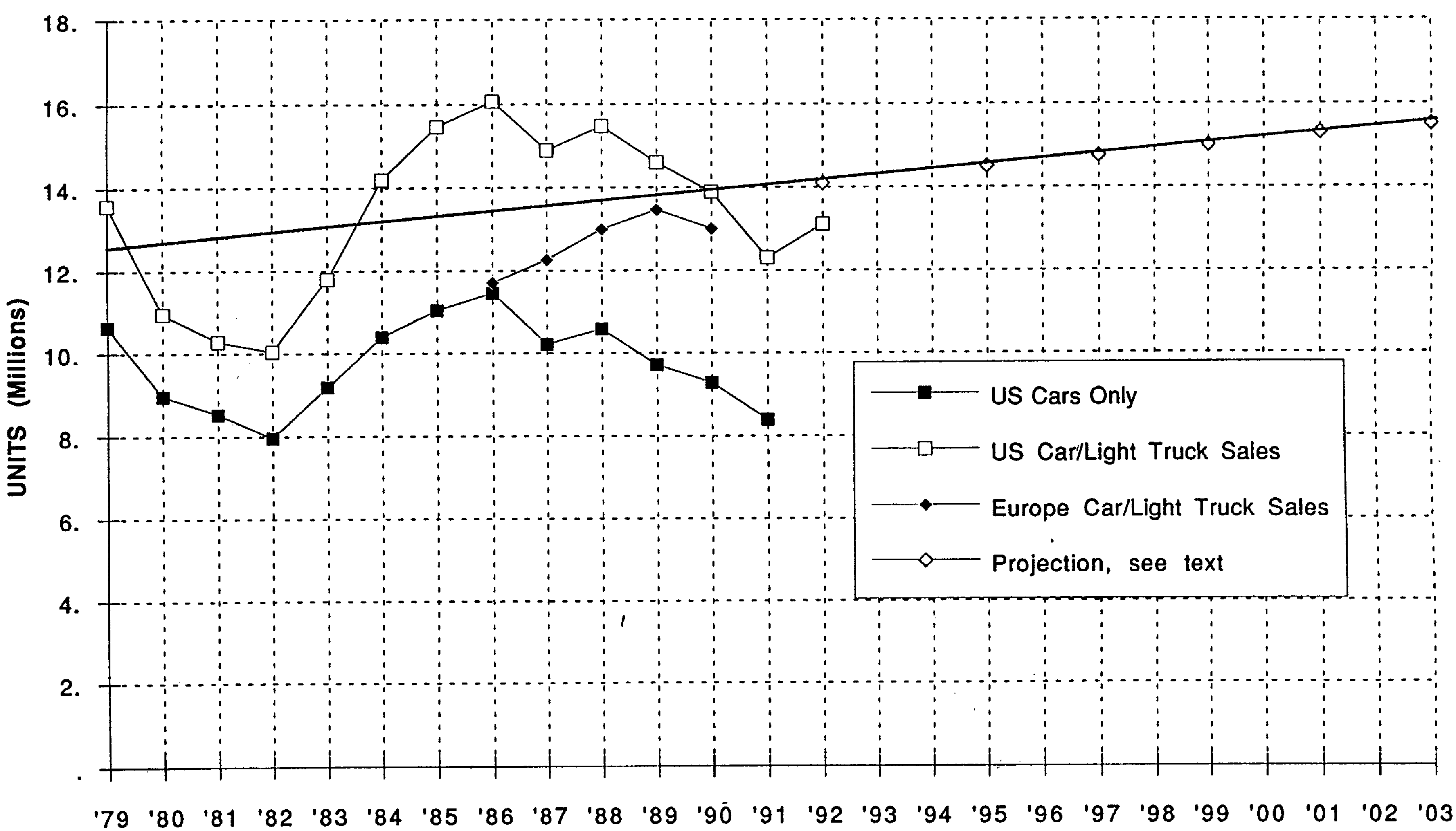
The Electric Vehicle industry in the United States is a growth industry, and is far from mature. This makes estimating the size and composition of the market difficult, since there is little data on actual consumer preference, and on product availability. This market analysis will therefore first segment the existing US light vehicle market, and then consider experience with the Mini-el in Europe. Since California has taken a leading role in the introduction of Electric Vehicles, California light vehicle sales are examined. The effect of Zero Emission Vehicle requirements will be considered, to develop an estimate of the size of the US EV market. Finally the Mini-el is compared with other available products based on price, range, speed, and safety considerations, in order to estimate market share. Prospective customer surveys are considered to validate these market share estimates. The results of the study are then summarized in a Mini-el Sales Forecast for 1993 to 1998.

Total Light Vehicle Market

Light vehicles are defined as those having a curb weight less than 6000 Lb (2700 kg) in the State of California Vehicle Code. These vehicles have the same use as the Mini-el, which is that they are primarily used for transportation of people. It is useful to examine and segment the total light vehicle market in the U.S. and in Europe. Figure 1 provides actual U.S. sales from 1979 to 1991, and actual sales in Western Europe from 1986 to 1990. Total U.S. sales are projected at a growth rate of 1% per year, which approximates the rate of population growth. (US Population; 1980=226.5M, 1990=248.7M, 1.01e10*226.5M=249M, Reference 11). Review of the data used to make the tables in this report shows that annual vehicle sales are a reasonably consistent fraction of the population of a region, for a given year.

Examination of Figure 1 reveals that US vehicle sales are quite cyclic, having increased about 60% from 1982 to 1986, and then decreasing 37% from 1986 to 1991. It can also be seen that the US is a little larger market than Western Europe. By inspection of Figure 1, 1990 is assumed to be a valid point from which to project the size of the total U.S. light vehicle market. Similar projections will be used as a basis for calculations of Electric Vehicle market size.

FIGURE 1
Total Car and Light Truck Sales
U.S. & Europe



Ref. Automotive News, 5/29/91 & Ward's Automotive Reports, 1/13/92•William R. Warf 6/26/92

The Western European Market

The Mini-el has been sold in several Western European countries, as shown in Table 1. These countries account for about 50% of light vehicle sales in Western Europe. Table 1 provides a population breakdown and total light vehicle sales in the Mini-el European target countries. The calculated sales per capita value of 0.0361 will be used to calculate the relative depth of the US market.

The Mini-el has achieved sales of approximately 1000 units per year over the last five years in the European target countries. Based on the data provided in Table 1, Mini-el sales amount to 0.00015 or 0.015% of vehicle sales.

The California Market

In September 1990 the California Air Resources Board (CARB) adopted a requirement that by 1998 2% of California vehicle sales will be zero emission vehicles. This requirement is increased to 5% in 2001, and 10% in 2003. Other States, primarily in the North Eastern part of the U.S., are considering adoption of the same requirement. Figure 2 provides a projection of California light vehicle sales, and illustrates the statutory minimum size of the EV market. The projection uses 1.012 per year market growth factor. Assuming that technologies other than electric drives remain non-viable for zero emission vehicles, the California electric vehicle sales requirement will be about 36,000 vehicles total in 1998, and 93,500 in 2001.

Figure 2 also shows a 1991 market of 1000 electric vehicles per year. This market size estimate is based on current EV activities in California. Most EV's are conversions which cost between $10 and $30 thousand. It is also noted that California Senate Bill SB 2600 (9/30/90) provided for a $1,000 State Income Tax credit for qualified "low emission vehicles", and that the annual dollar limit budgeted was equivalent to 750 vehicles per year. Sales would have exceeded this limit if more viable Electric Vehicles, such as the Mini-el, were available.

The Effect of Zero Emission Vehicle Minimum Sales Laws

California Air Resources Board requirements have significantly stimulated the Electric Vehicle market. This stimulating effect may be summarized in five points. First, other States in the United States are re-examining their clean air assuring statutes to see if implementing rules similar to California is viable and beneficial. Second, Manufacturers have a definite target minimum sales quantity to strive for, stimulating Electric Vehicle development. Third, Utilities have commenced active involvement in estimating the impact on power demand, and in planning to meet this demand.

TABLE 1
Western Europe
Population and Light Vehicle Sales

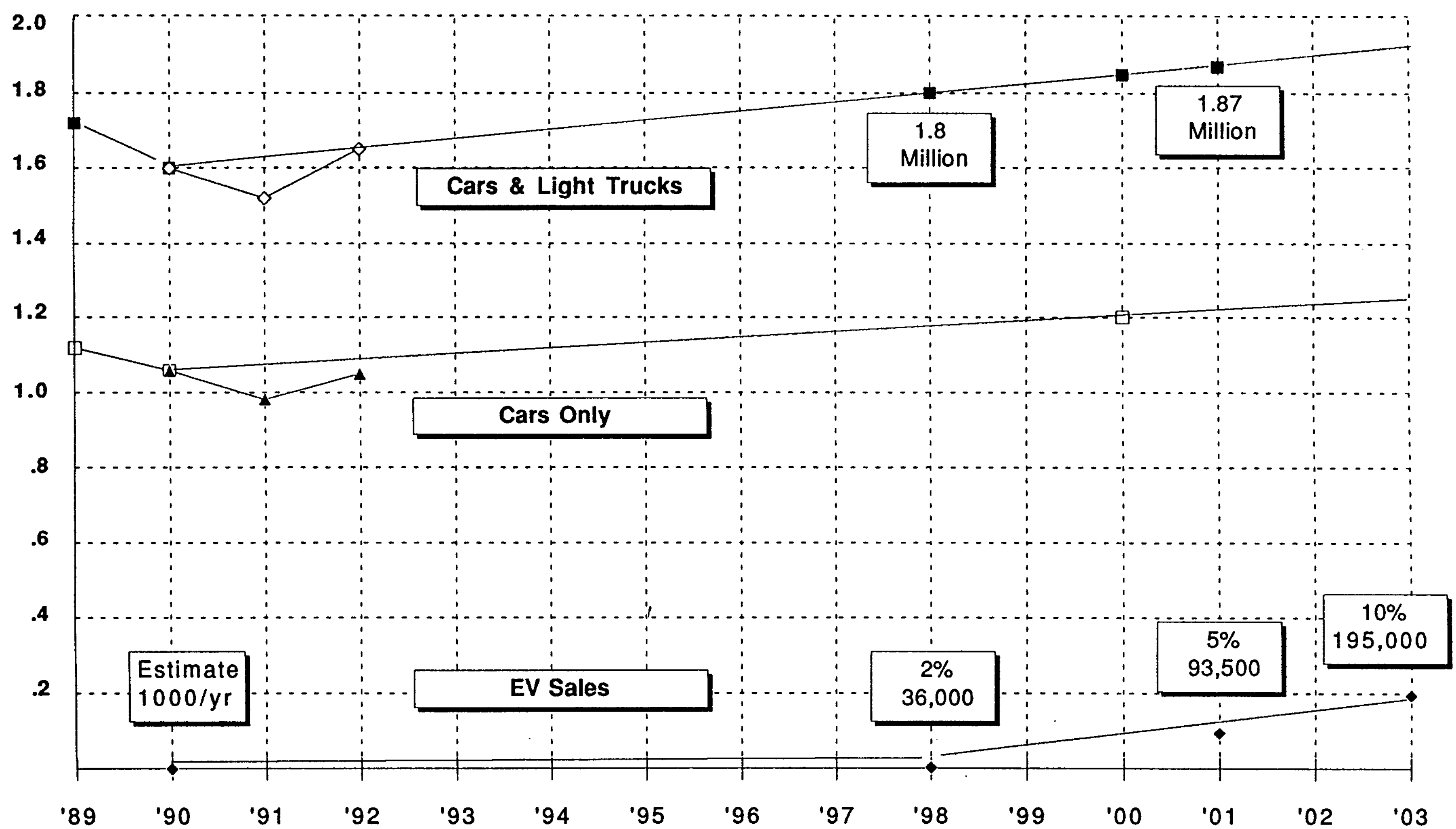
Mini-El *Target Countries*	**Population** 1000's	**Sales '90** 1000's	**Sales '90** Per Capita	**Sales '89** 1000's	**Sales '89** Per Capita
Germany	79,220	3,040.8	.0384	2,832.0	.0357
Switzerland	6,737	323.0	.0479	339.0	.0503
United Kingdom	57,380	2,008.9	.0350	2,300.9	.0401
Denmarke	5,138	80.9	.0157	74.4	.0145
Netherlands	14,980	502.7	.0336	495.7	.0331
Belgium	9,927	473.5	.0477	439.8	.0443
Sweden	8,602	229.9	.0267	307.1	.0357
Norway	4,271	61.8	.0145	54.9	.0129
SubTotal	186,255	6,721.5	.0361	6,843.8	.0367
Other	191,550	6,535.5	.0341	6,623.2	.0346
Western Europe	377,805	13,257.0	.0351	13,467.0	.0356

• *Other includes Austria, Ireland, Finland, France, Greece, Italy, Luxembourg, Portugal and Spain*
Data from Automotive News 5/29/91; Rand McNally & Co. World Atlas

William R. Warf 6/26/92

FIGURE 2
California Light Vehicle & EV Sales

'1989, '1990, 2000 Data From Automotive News, 5/29/91---1991 Sales & 1992 Projection from Ward's Automotive Report 1/13/92



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Fourth, more attention is being focused by the media on Electric Vehicles in general, providing an increase in public awareness, and creating anticipation of EV availability. Fifth, Electric Vehicle sales will exceed quantities which would have occurred in the absence of these laws. Each of these points is examined briefly in the following.

1. Other States: Massachusetts, Connecticut, New York, New Jersey, and neighboring States are actively engaged in deciding whether to adopt California's Low Emission Vehicle program, or the less stringent Federal law. According to a telephone interview with a representative of NESCAUM (North East States For Coordinated Air Use Management), the 8 Eastern states involved in NESCAUM are likely to adopt the California rule, on the same schedule. It is noted that under federal law this requirement must be adopted at least two years before the minimum sales figure goes into affect, before 1996 for 1998 implementation, for example. The NESCAUM members include Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, and New Jersey.

2. Manufacturers: Increased Electric Vehicle development is evidenced by an increased presence of electric concept cars at the major Auto Shows world wide, and the increased number of press releases by major auto manufacturers. Most of the major manufacturers achieve a product development cycle of about 6 years, while the best develop and market new products in just under 4 years (Reference 4). This should result in a significant increase in the number of Electric Vehicles available starting in 1996.

3. Utilities: Power generating utilities will play a major role in our ability to use electric vehicles by providing recharging facilities, and in some cases incentives to make Electric Vehicle use more economic. The Sacramento Municipal Utilities District, for example, plans to offer off peak charging energy cost to consumers of 4.2 cents per kiloWatt-hour, as part of their comprehensive Electric Vehicle Program. 4.2 cents per kiloWatt-hour is significantly lower than electric rates in most parts of the US, as is shown in Appendix 1.

The planning cycle for Utilities is typically 20 to 30 years, because of the length of time required to plan, permit, and construct additional power generating facilities. The NESCAUM report showed a small, 3% impact on power demand assuming "off peak" night-time charging, between now and 2010. The Utilities will play a major role in promoting the use of Electric Vehicles, since this represents increasing business, and allows an environmental advocacy marketing position.

4. Media: The media will continue to cover the development of Electric Vehicles, since a legal requirement for the minimum number of sales of a product is an action with little precedent. In addition, more coverage of environmental issues in the media is a

reflection of the public's interest. Most environmental issues have tended to cause plant closings or business relocations because of compliance costs, increasing un-employment. The Electric Vehicle business promises to answer an environmental issue with creation of new jobs, which will certainly be big news.

Media coverage will help make state capitals excellent market introduction starting points, as law makers participate in the early use of Electric Vehicles.

There is a tendency in the current media for exaggeration of the facts about Electric Vehicles. Market size will depend on battery development, and upon public expectation as to the capabilities of electric cars. Data on the Impact for example, is largely based on the performance of an all fiberglass prototype, which does not meet crash safety standards, and probably has it's batteries changed frequently. Data comparing conventional cars to EV's is presented later in this Market Estimate.

<u>5. Electric Vehicle Sales:</u>

Sales of Electric Vehicles will exceed quantities which would have been expected in the absence of the CARB rule. Over the last five years, Mini-el sales have averaged a small percentage of light vehicles sold in the countries in which it is marketed, which were shown in Table 1. The CARB rule has the effect of inflating the market, and creating more publicity and political activity devoted to electric vehicles than would have naturally occurred. A well developed, low price electric vehicle such as the Mini-el should quickly gain acceptance and sales in this market place.

<u>Selecting the Target US Markets</u>

The distribution system for the Mini-el will be set up first in regions which have the highest probability of Electric Vehicle sales. As discussed above these regions will certainly include States which are considering adopting minimum requirements for Zero Emission Vehicles. Additional considerations for selecting target markets include population density, market depth, conditions favorable to EV use, and environmental movement strength.

For the purposes of this estimate, sixteen States were selected as distribution areas to be cultivated first, as they best fit the above criteria. Population and vehicle sales data for the States selected are provided in Table 2. The target market represents 41% of the US population, and accounts for 44% of US light vehicle sales. The vehicle market in these target states is approximately equivalent to the size of the Mini-el target countries in Europe.

It should be emphasized that Mini-el sales need not be confined to those States shown. Target market areas were selected as starting regions for the purpose of estimating sales in the first five years after Mini-el's US introduction. These states will also be assumed to be those in which the bulk of US Electric Vehicle sales will be concentrated.

TABLE 2

Target States For Mini-El Introduction

States	Population 1000's	Car Sales 1990 1000's	Car Sales 1990 % Per Capita	Car & Light Truck Sales 1990 1000's	Total Sales 1990 % Per Capita	Projected Total Sales 1998 1000's
California	29,760	1,060	3.56	1,599	5.37	1,800
Arizona	3,665	61	1.66	133	3.62	150
Hawaii	1,108	72	6.49	98	8.82	110
Oregon	2,824	93	3.29	166	5.89	187
SubTotal	37,357	1,286	3.44	1,996	5.23	2,247
Connecticut	3,287	141	4.28	187	5.70	211
Massachusetts	6,016	234	3.89	307	5.10	346
New Jersey	7,730	372	4.81	484	6.26	545
New York	17,990	584	3.25	786	4.37	885
New Hampshire	1,109	48	4.34	74	6.63	83
Rhode Island	1,003	34	3.41	45	4.49	51
Vermont	563	21	3.65	33	5.88	37
Maine	1,228	37	3.04	60	4.92	68
SubTotal, NESCAUM	38,926	1,471	3.78	1,976	5.08	2,226
Delaware	666	41	6.17	61	9.16	69
Maryland	4,781	258	5.40	364	7.62	410
Virginia	6,187	241	3.90	358	5.79	403
Florida	12,937	791	6.12	1,049	8.11	1,182
SubTotal, East Coast	63,497	2,802	4.41	3,808	6.00	4,290
Total East & West	100,854	4,088	4.05	5,804	5.75	6,537
Total U.S.	248,000	9,160	3.69	13,964	5.63	14,875

Data from Automotive News 5/29/91; Ward's Automotive Reports 1/13/92, and Rand McNally World Atlas

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Germany and the United Kingdom have population densities of about 600 people per square mile, which is roughly equivalent to the population density of Massachusetts and Connecticut. California's population density is 188, while the United States as a whole has a population density of 68 people per square mile (reference 3). Areas with high population densities will have the largest air pollution problems, and the biggest incentive to use Electric Vehicles. In addition, average trip lengths are probably shorter in these areas.

The relative depth of vehicle markets is best indicated by the sales per unit population. In the United States, annual auto sales are about 5.6% of population as shown in Table 2. Europe's Sales per capita is about 3.5% as shown in Table 1. The US market is therefore about 1.6 times deeper than Europe. The target markets are both slightly larger on a per capita basis, being 5.75% of population in the US, and 3.61% in Europe. This results in the same relative depth. The relative market depth fact is evidenced by the number of second, third, and even fourth car's in US households. Select States with higher than average sales per capita and which fit the other criteria the are included in the target distribution states, even though they currently do not have clean air Zero Emission Vehicle mandates.

Estimate of US Electric Vehicle Market Size

The Electric Vehicle market is estimated by projecting 1990 light vehicle sales to 1998, and then calculating the probable EV Sales based on a fraction of total vehicle sales, as shown in Table 3. Two cases are provided. In the "probable case" I have assumed 2% of vehicle sales in California, Connecticut, Massachusetts, and Rhode Island, 1% in the balance of the NESCAUM States, and 0.2% in the balance of the target States. In the maximum case I have assumed 2.5%, 2% and 0.5% in the same categories. This gives a probable 1998 US Electric Vehicle market of 69,400 units, and a maximum market of 105,300 units.

A California statutory 1998 market of 36,000 units was previously estimated. Based on the estimates calculated in Table 2, California will account for about half of US Electric Vehicle sales through 1998.

It is expected that the number of units sold after 1998 will be a larger percent of total light vehicle sales, as Electric Vehicles gain acceptance and market share. This must be the case if the California and Northeastern State requirements are to be complied with. California Electric Vehicle sales in 2001 are projected as 93,500 (Figure 2). It is difficult to project the results of current research and development in Electric Vehicles, however the quantity and quality of available EV's is expected to increase dramatically starting in 1996.

TABLE 3

States	1998 Sales Light Vehicles Projection 1000s	1998 EV Market Probable Multiplier	Market	1998 EV Market Maximum Multiplier	Market
California	1,800	0.02	36,000	0.025	45,000
Arizona	150	0.002	300	0.005	800
Hawaii	110	0.002	200	0.005	600
Oregon	187	0.002	400	0.005	900
SubTotal	2,247	0.0164	36,900	0.0211	47,300
Connecticut	211	0.02	4,200	0.025	5,300
Massachusetts	346	0.02	6,900	0.025	8,700
New Jersey	545	0.01	5,500	0.02	10,900
New York	885	0.01	8,900	0.02	17,700
New Hampshire	83	0.01	800	0.02	1,700
Rhode Island	51	0.02	100	0.025	1,300
Vermont	37	0.01	400	0.02	700
Maine	68	0.01	700	0.02	1,400
SubTotal, NESCAUM	2,226	0.0128	28,400	0.0214	47,700
Delaware	69	0.002	100	0.005	300
Maryland	410	0.002	800	0.005	2,100
Virginia	403	0.002	800	0.005	200
Florida	1,182	0.002	2,400	0.005	5,900
SubTotal, East Coast	4,290	0.0076	32,500	0.0135	58,000
Total East & West	6,516	0.0106	69,400	0.0161	105,300

Data from Automotive News 5/29/91; Ward's Automotive Reports 1/13/92, and Rand McNally World Atlas

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Autofacts Inc. of West Chester, Pennsylvania estimated the EV market at 290,000 units in 2001. If this estimate is correct, California will represent at least 32% of the US EV market in 2001. (Reference 5)

A report prepared for NESCAUM (Reference 6) has projected Electric Vehicle use on the basis of the entire NESCAUM region adopting and complying with the California Electric Vehicle Program requirements for minimum sales. The report justifies this by referencing other reports which project significantly higher EV sales.

This Market Estimate is only concerned with projecting Mini-el sales for five years, through 1998. It is however interesting to consider Figure 3, which summarizes the total US Electric Vehicle market as estimated above, through 2003.

Estimate of Mini-el Market Share

The first and most common questions people ask when looking at the Mini-el are how much, how fast, how far, and how safe? This estimate of Mini-el sales will be based on estimating how the Mini-el compares to other personal transportation vehicles by answering these questions. Mini-el's share of the probable electric vehicle market will be estimated on the basis of these factors.

A large part of sales will be due to the public's environmental concern. The electric vehicle market is likely to be larger than estimated solely on technical issues. Consideration of technical issues should provide a conservative estimate of minimum sales to assure a profitable factory.

How Much?:

The Mini-el is reasonably priced. At a target price of $7000 it is a low cost opportunity for people to own and experience an Electric Vehicle. It is also likely that leasing arrangements, such as the one proposed by SMUD (reference 7), will prove both convenient for consumers, and profitable for the party furnishing the lease service. SMUD states the lease arrangement will help overcome the public's uncertainty about Electric Vehicles.

Based on announced product developments, it is un-likely that many Electric Vehicles priced less than the Mini-el will soon be offered in the US. Tax credits and other incentives may help place the Mini-el in an even more affordable range.

Only 5% of the vehicles sold in the United States have a price less than $7000. This suggests that 95% of car buyers could afford a Mini-el. These inexpensive cars are likely to be purchased as second or third vehicles intended mostly for local use, and could therefore likely be considered an alternative by prospective Mini-el buyers. A list of Small Cars; IC Engine and less than $7000 appears in Table 4. The total number of these cars sold (449,600

FIGURE 3
Total U.S. Electric Vehicle Market

Values in 1998 From Table 3

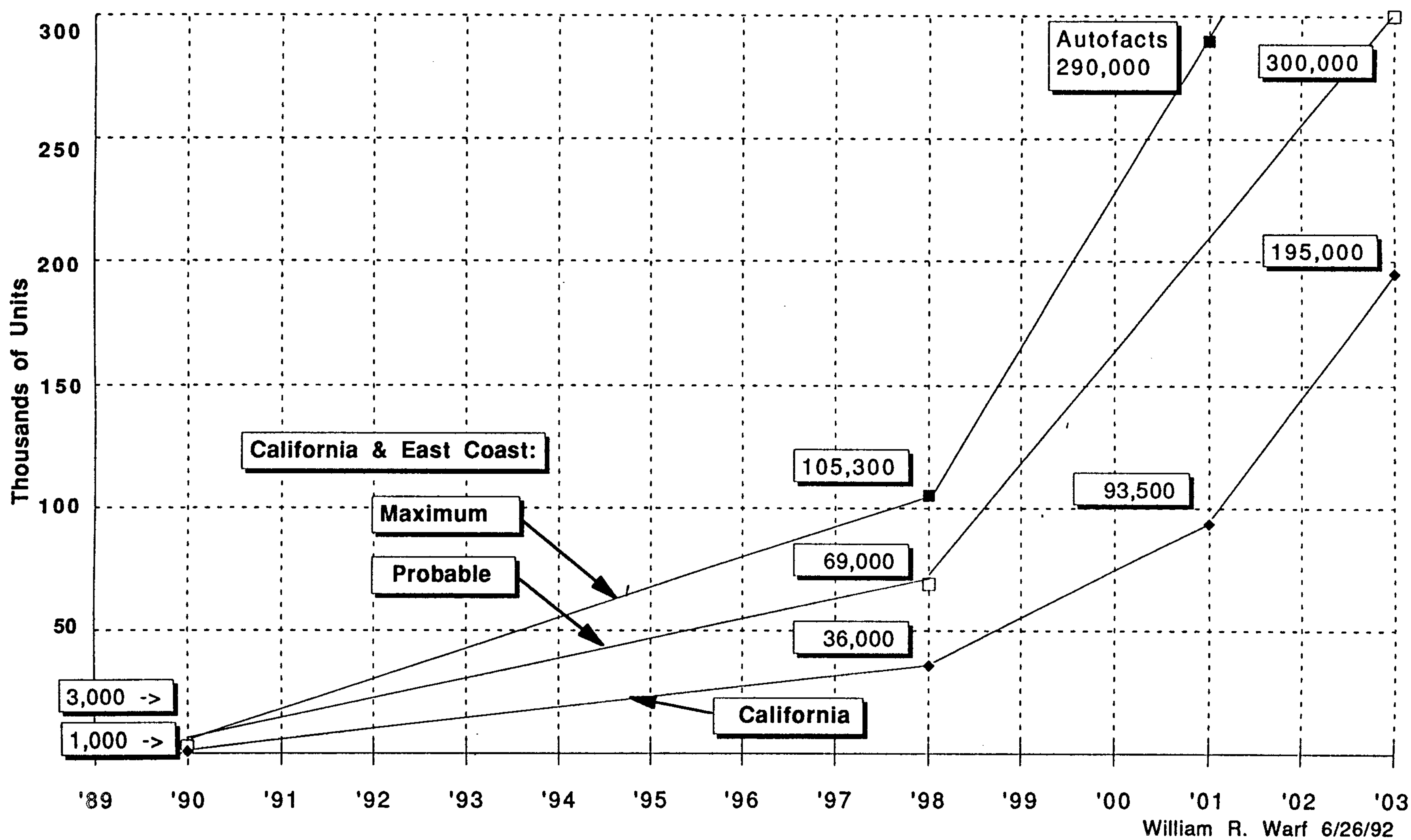

TABLE 4
Small Cars:
Internal Combustion Engine & Less than $7,000

Model	Produced In	Price	1990 Units	1991 Units	% of 1991 Vehicle Sales
Suzuki Samurai	Japan	$6,299	4,900	4,400	0.04%
Daihatsu Charade	Japan	$6,633	6,400	6,200	0.05%
Subaru Justy	Japan	$6,645	14,300	6,700	0.05%
Suzuki Swift	Japan/Canada	$6,899	6,500	4,800	0.04%
Toyota Tercel	Japan	$6,588	90,800	102,000	0.83%
Mazda 323	Japan	$6,949	23,000	18,400	0.15%
Geo Metro	Japan/U.S.	$6,795	97,200	90,400	0.73%
Dodge/Plymouth Colt	Japan	$7,067	39,600	27,300	0.22%
Honda Civic	U.S./Japan/Canada	$6,995	70,000	62,300	0.51%
SubTotal Japan:			352,700	322,500	
Hyundai Excel	South Korea	$6,375	100,600	66,400	0.54%
Ford Festiva	South Korea	$6,648	52,500	42,000	0.34%
Mitsubishi Precis	South Korea	$6,469	4,700	3,300	0.03%
SubTotal Korea:			157,800	111,700	
Volkswagon Fox	Brazil	$7,370	22,600	13,400	0.11%
Yugo G.V.	Yugoslavia	$4,825	4,000	2,000	0.02%
Grand Total			537,100	449,600	3.66%

[1] Half Canada; Half Japan Assumed

[2] Increased U.S. build in 1991

[3] 1/3 each U.S., Japan, Canada. Model range 7->12 K$, base unit
Unit quality estimated as 70,000 of 261,502 total

Data from Automotive News 5/29/91 & Ward's Automotive Reports 1/13/9

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units, 1991) is roughly equivalent to total Motorcycle sales in the US, which amount to 462,000 units (reference 8).

The best selling cars included in Table 4 are the Geo Metro, Toyota Tercel, and the Hyundai Excel. These are compared with the Mini-el in Figure 4. It is noted that these figures bear out how dramatic the difference between Electric Vehicles and IC engine cars is in terms of performance, range, and flexibility of use. Customers will buy the Mini-el primarily because of environmental concern, operating cost, and practicality. The useful life of our internal combustion cars would be extended if they were not used for short trips, since the warm up time is when the most engine wear occurs.

The Mini-el fares much better when compared with electric vehicles available today, as shown in Table 5, and illustrated in Figure 5. The least expensive of these is the ATW Optimax GL, which costs $16,900 to $21,000, with only modest range and speed advantages, and seating for two. The Mini-el is also compared with European EV's in Figure 5A.

An important advantage of the Mini-el is the fact that only 3 lead acid batteries are needed. Most of the other electric vehicles being tested in the US use 10 to 20 batteries, while the European EV's use 4-8. With the Mini-el's light weight and well developed electronic controls, the batteries last as long or longer than other electric vehicles. Replacement of batteries every 18 months or 200 cycles is therefore much more affordable with the Mini-el.

It is possible to ruin the batteries in an electric vehicle in a few cycles. Most of the damage occurs from too deep a discharge, or from improper charging. The Mini-el has been on the market for 6 years, and has sustained development lacking in most other EV's. The current counter and battery charge board are interactive in controlling the discharge and recharge of the batteries. The recharging cycle is optimized utilizing a special algorithm, to match the re-charging cycle to the type of discharge cycle experienced. The algorithm also provides for a special regeneration cycle once in a multiple of recharge cycles. This helps to equalize the batteries, and provide the maximum battery life. Maximum battery life is clearly a cost advantage for Mini-el.

<u>How Fast?:</u>
The average top speed of the other electric vehicles analyzed in Table 5 is 58 miles per hour. With a top speed of 50 km/h (31 mph) the Mini-el is comparable to Mopeds and Scooters in terms of performance. 1991 sales of Mopeds and Scooters in the US was about 60,000 units, about 14% of motorcycle sales (reference 8). The lower speed of the Mini-el is a safety advantage. The Mini-el is certainly more safe than a moped, and it will keep you dry in a rain storm, and warm in the snow.

FIGURE 4
Comparison of Mini El to Best Selling Internal Combustion Cars < $7,000

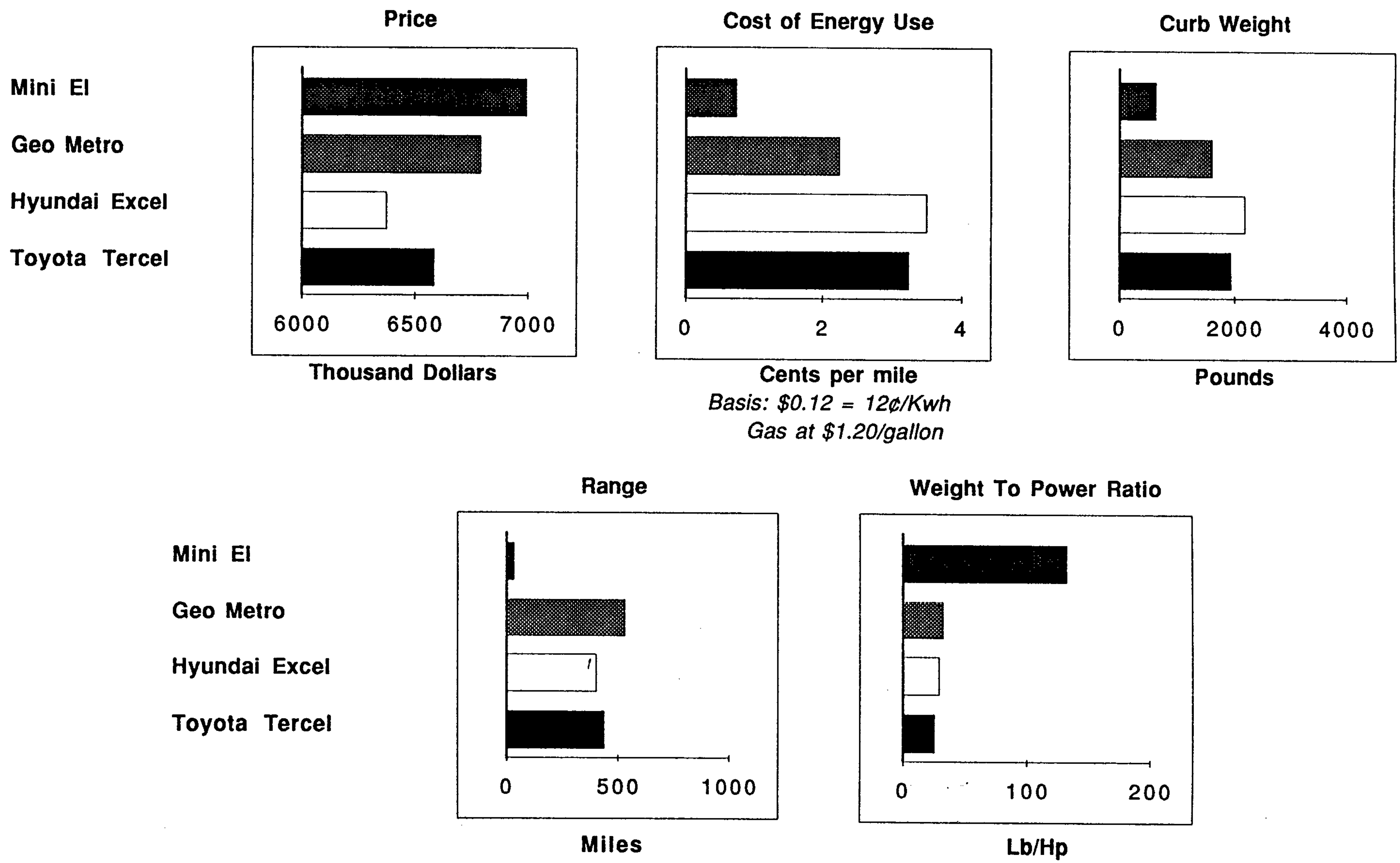

TABLE 5
Electric Vehicles

Vehicle	Top Speed mph	Range mi.	Weight lbs.	Est. Energy Use kWh/mi.	Price
Impact	75	120	2,200	0.14	NA
G. Van	52	60	7,672	1.00	NA
S.C.G. Festiva	60	60	3,000	0.45	$27,500
Solectria Force	60	60	2,142	0.25	$25,000
BMW E-1	75	130	1,985	0.30	NA
Mini El	30	30	638	0.05	$7,000
ATW Optimax 25GL	66	60	1,584	---	$16,900
Fiat Panda Electra	43	43	---	---	NA
Mean	57.62	70.37	1924 [1]	---	---
Standard Deviation	15.56	35.5	782 [1]	---	---

[1] Not counting G. Van

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FIGURE 5
Comparison of Mini El to Other Electric Vehicles

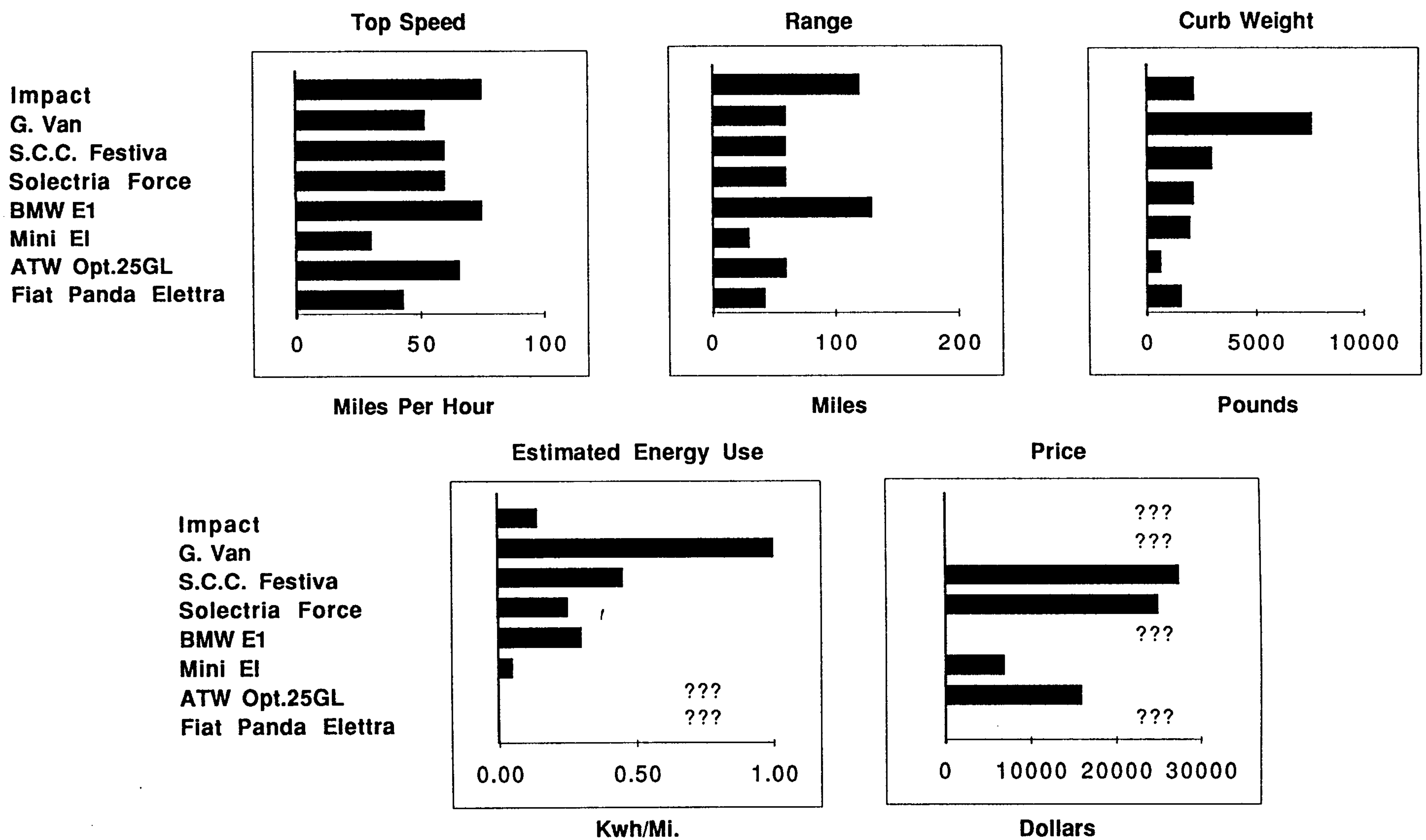

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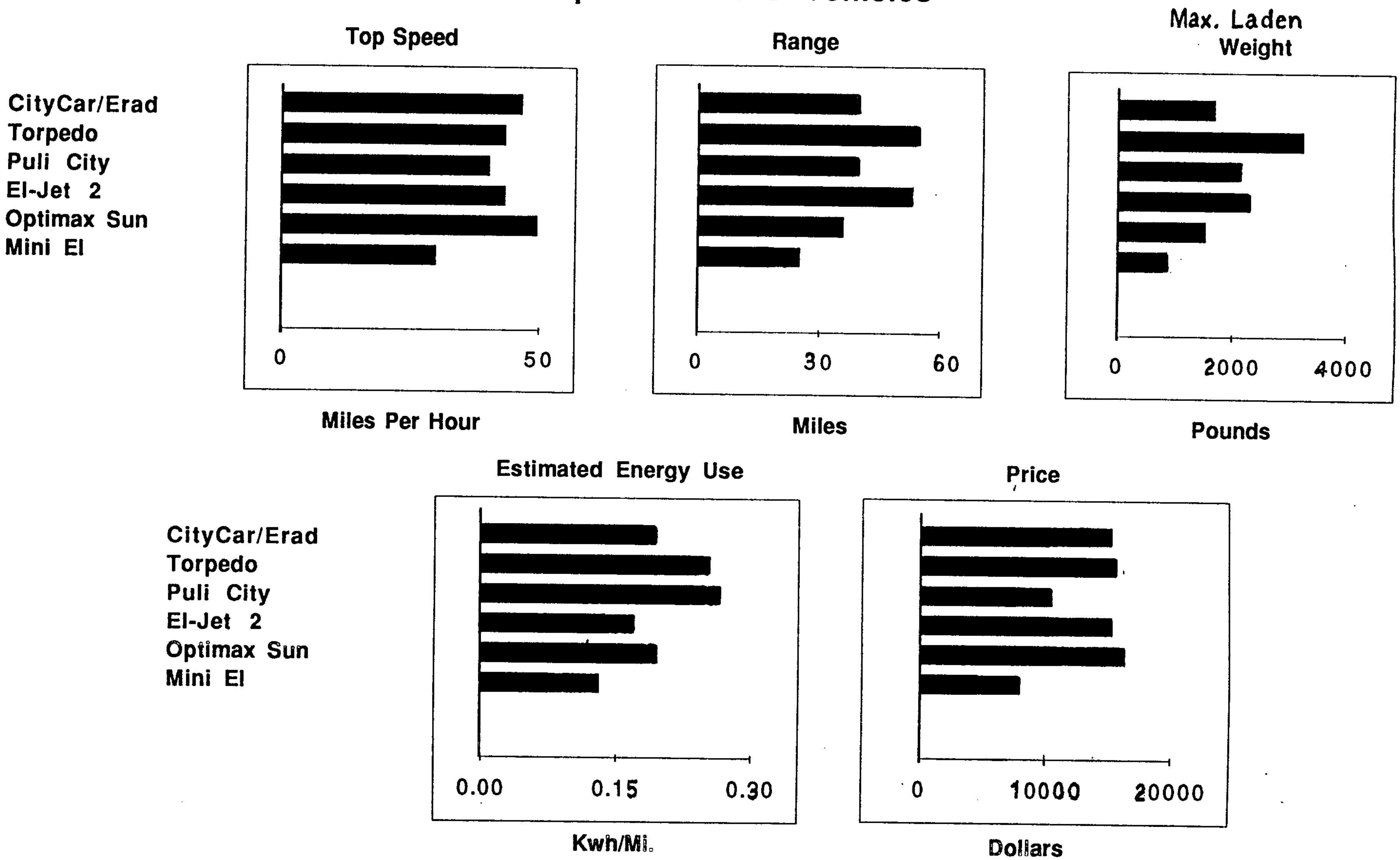
FIGURE 5 A
Comparison of Mini El to European Electric Vehicles



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It is important to note that the Mini-el has a special current control box to limit the total and rate of discharge, to ensure long battery life. Many EV's allow discharge of the batteries to 80% or more, while the Mini-el is limited to 60%, to prevent ruining the batteries. This is one of the reasons prototypes can demonstrate such dramatic performance characteristics, they are not subject to daily use, and do not need long battery life.

Reading of the SMUD literature (reference 7), and discussions with potential Mini-el buyers suggests that vehicles capable of speeds of 40 to 75 miles per hour will make up the bulk of EV sales. Plotting the speed capability information from Table 5 on a normal curve suggests the Mini-el with 30 mph capability will achieve 5.59% penetration of the Electric Vehicle market, or about 3500 units in 1998. This is shown graphically on Figure 6. The statistical method is from Reference 9.

<u>How Far?:</u>

The Mini-el has a range of about 30 miles. Department of Transportation data shows that more than 50% of vehicle miles are accumulated in round trips less than 40 miles in length. This fact is referenced in market studies by the utilities (including reference 6), and has often been mentioned in EV advertising and news stories. The SMUD Electric Vehicle Program literature (Reference 7) states that the Sacramento area is only about 30 miles in diameter, and the average trip length is 11 miles or less. The Mini-el can thus fulfill the transportation needs of many.

The NESCAUM "Impact of Electric Vehicles..." report (Reference 6) used an average daily EV mileage of 37.65 miles to estimate energy demand. This report suggests that people using a vehicle with a rated range of 100 miles would want to recharge the vehicle after a trip of 40 miles to assure a comfortable margin of stored energy for the return trip.

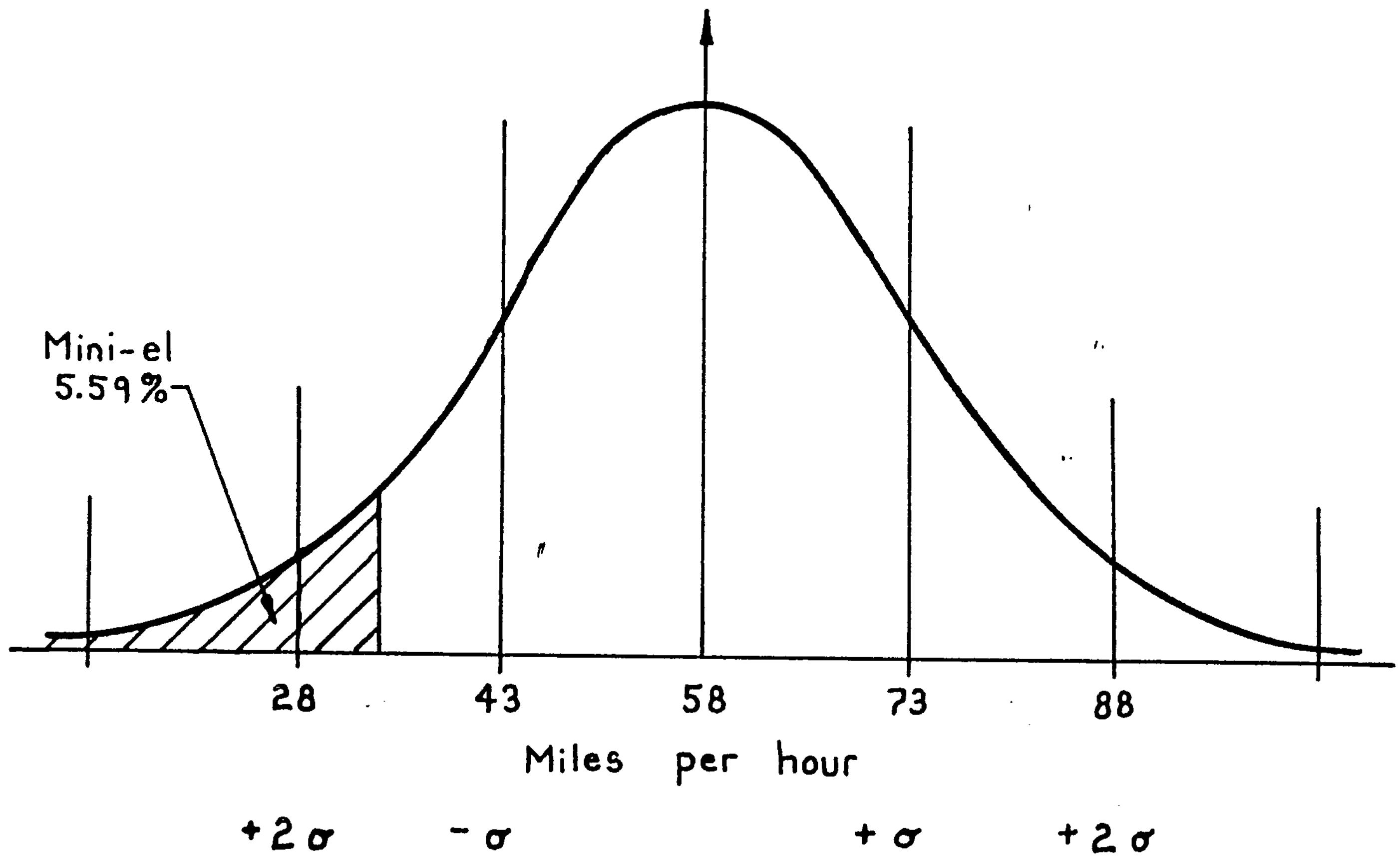
It is assumed that EV consumers will not try to use EV's for trips much longer than 55-60 miles. Taking the mean daily use range for EV's as 40 miles, and the standard deviation for the likely population as 15 miles, the Mini-el has the capability of satisfying 25.5% of EV consumers, as shown in Figure 7. The statistical method is from Reference 9. Since consumers will likely be concerned with reserve range capability when buying an Electric Vehicle, capability range is multiplied by 1.6 to estimate Mini-el acceptance at 11.5% of the EV market. It is likely that this potential share may increase as charging facilities at shopping centers and work places are developed. Consumer awareness of EV capabilities and of the benefits of EV use will also increase the usage of EV's for short trips.

The mean advertised range of the Electric Vehicles in Table 5 is 70.37 miles, and the standard deviation is 35.5 miles. Figure 8 shows Mini-el market share of 9.18% if the mean range is taken as 70 miles, and the standard deviation is taken as 30 miles.

FIGURE 6

TOP SPEED CAPABILITY

Electric Vehicles



It is noted that the range achieved by prominent European EV's is on the order of 40 miles, as shown in Figure 5A. This seems to indicate that many of the prototypes considered in table 5 are optimistic, and would indicate Figure 7 as more indicative of probable market share than Figure 8.

As pointed out above in the examination of price, the Mini-el is a bargain compared to other EV's available today. Dividing the purchase price by the advertised range for four of the vehicles in Table 5 gives the following value comparison:

Mini-el.............$233/mile of range
Solectria Force.....$416/mile of range
ATW Optimax.........$393/mile of range
Solar Car Festiva...$458/mile of range

The Mini-el is less expensive to keep on the road because of the smaller number of batteries to be replaced, and because of City Com's well developed discharge and recharge controls.

How Safe?:

Safety is a big issue in the personal transportation market. There are a number of relatively new laws for side impact crash worthiness, air bag installations, active seat belts, and helmet use on motorcycles. The 55 mile per hour speed limit was enacted to increase safety and decrease fuel use.

Mini-el has been on the Market in Europe for 6 years, and has been involved in only one serious injury accident. No fatalities have been recorded. This may be due to the good visibility of the Mini-el in traffic, and due to the relatively low speeds involved with Mini-el use.

Most people in the US associate safety with big heavy vehicles, which presents an interesting challenge to Electric Vehicle manufacturers. In Europe, safety is addressed by more rigorous driver training and by more frequent vehicle safety inspections. This European practice is more consistent with the price of fuel, which is 2.5 to 3 times higher than in the US.

The Mini-el will be registered as an electric vehicle or a motorcycle, depending on the evolution of the laws. The Mini-el may not require crash testing in the same manner as 65 mph passenger cars.

Since most US consumers view safety in terms of vehicle weight, the market share for Mini-el in the US can be estimated accordingly. Taking the Electric Vehicles in Table 5 as representative of available products in the next five years, and discounting the G-van as not applicable to this analysis due to operating cost and very heavy weight, the mean acceptable Electric Vehicle weight is expected to be 1924 lbs (875kg), and the standard deviation is 782

FIGURE 7

LENGTH OF TRIP (MILES)

TYPICAL DAILY ELECTRIC VEHICLE USE

Mini-el-CAPABILITY-vs-ACCEPTANCE

Mini-el has a 30 mile range

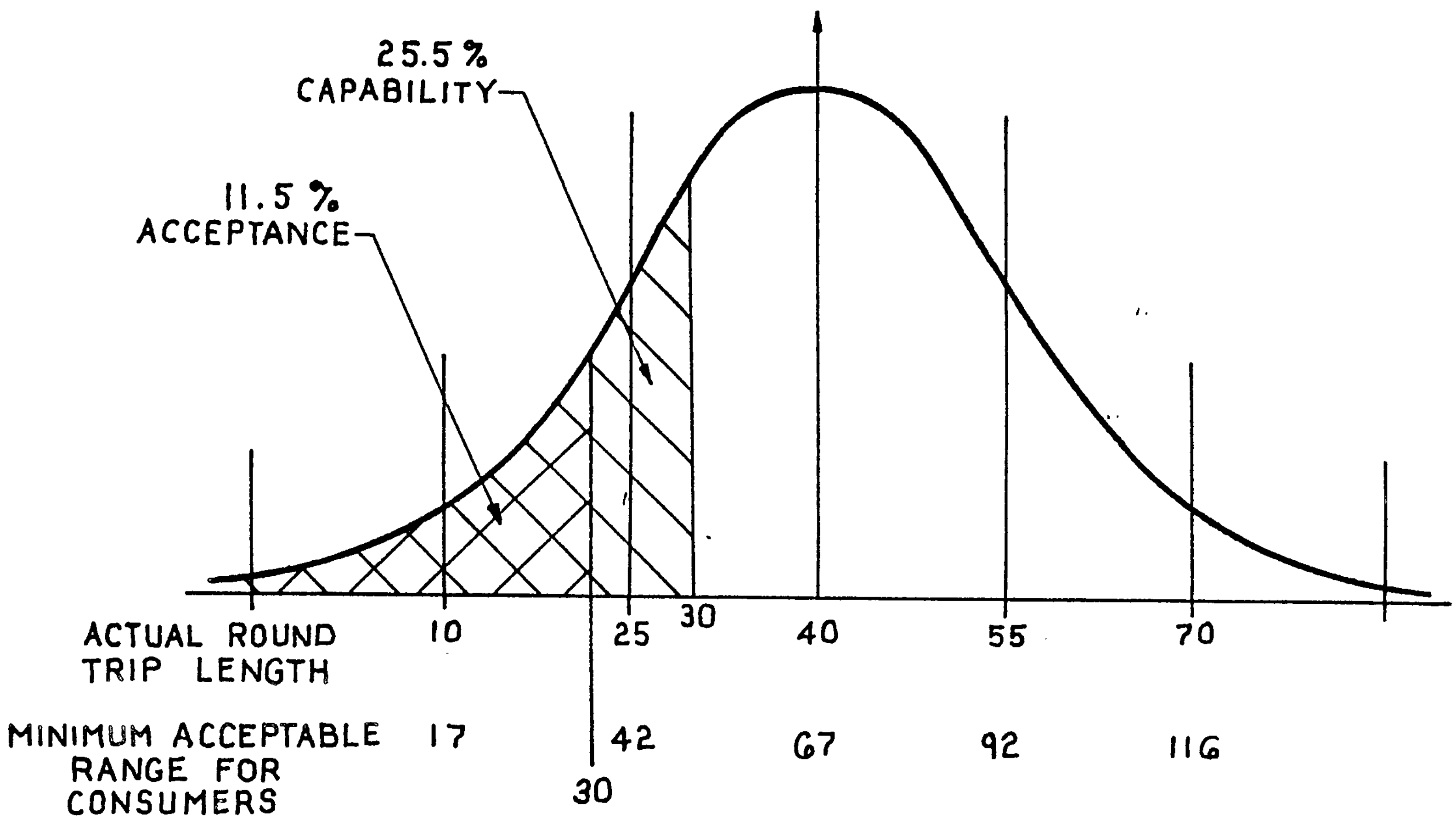
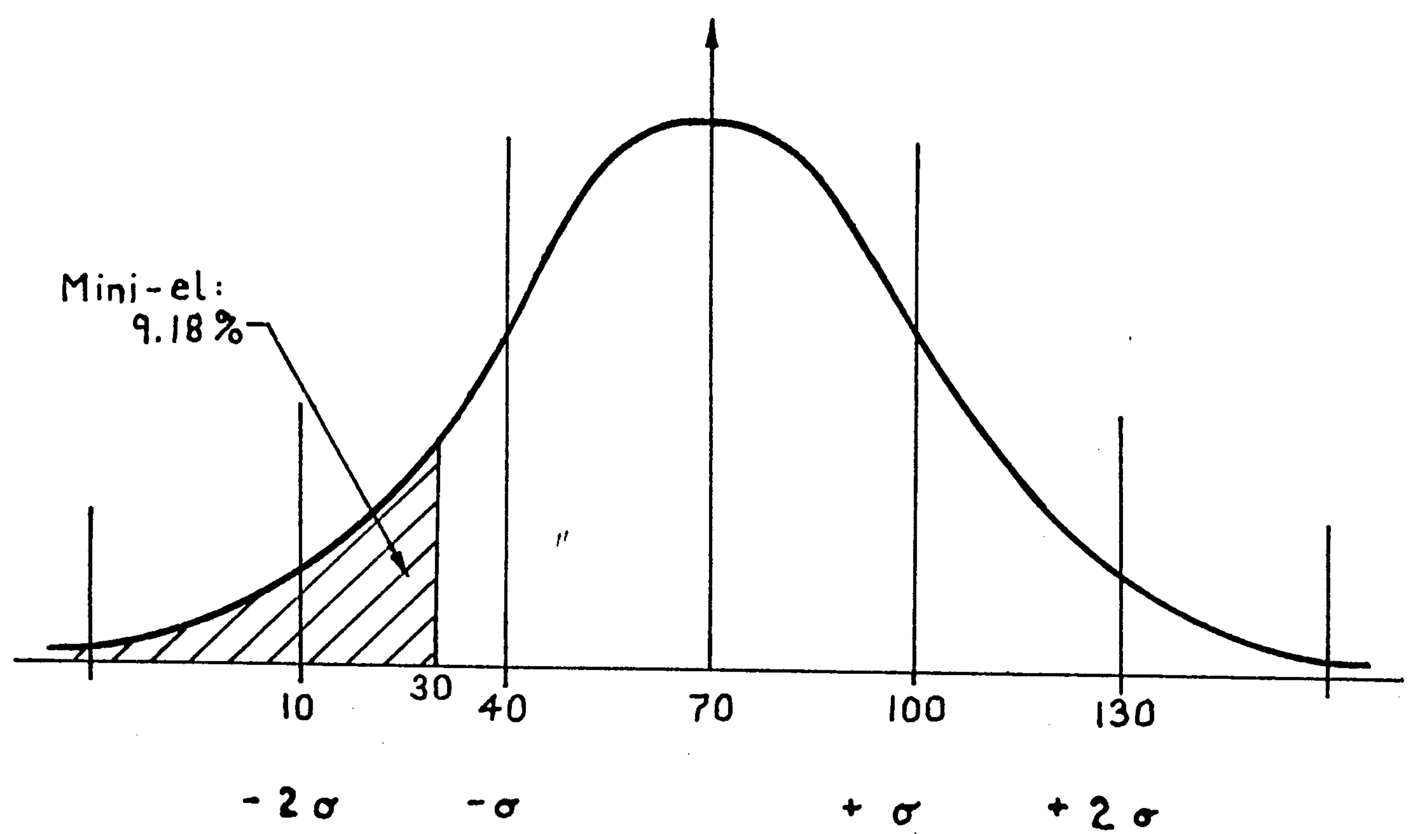


FIGURE 8

RANGE, MILES

Available Electric Vehicles



lbs. From this perspective, as shown in Figure 9, the Mini-el should achieve 5.05% of the electric vehicle market.

It is noted that the 15 best selling cars in the US have an average weight of 2676 lbs (1216 kg). In the SMUD literature (reference 7), light weight electric vehicles are expected to weigh 2000 to 3000 lbs. This is contrasted to an average weight of European EV's of about 1700 lbs, as shown in Figure 5A.

The light weight of the Mini-el actually represents an elegant engineering solution. One key to acceptance of the Mini-el will be to emphasize the Mini-el as being very easy on the environment because of it's light weight, low energy use, and quietness. The Mini-el is indeed a viable solution to short trip personal transportation needs.

Market Survey Results

Market Survey questionnaires were distributed in Davis, California, during the Whole Earth Festival on May 8-10, 1992. Davis is the home of The University of California at Davis, and is famous for it's population of bicycles. Davis has bicycle lanes along almost every street.

A graphic analysis of the surveys taken at Davis appears in Appendix 2, and the results are discussed in the following. In general, the surveys agree with the above discussion of Mini-el market share. It must be remembered that the represented sample includes people with more environmental concern than the average population.

The large majority of respondents could use the Mini-el to travel to work and to shopping. Because Davis has a significant bicycle population, there are bike lanes in almost all Davis streets, and the speed issue is not as important as in other cities. 93% of the responses indicate a one way distance to shopping less than 10 miles, and 60% indicate a one way distance to work less than 10 miles.

People spend most of the time in their vehicles alone. From the survey, 58% of respondents spend more than 75% of driving time alone. The drive alone time should prove to be higher in working suburbs than in Davis.

The fourth survey question was misunderstood by many respondents, because it is indirectly worded. It asks "what is the minimum range between fill up's of your second car?" The intent of the question was to investigate needed range between charges. Only 72 of 108 respondents answered the question; some replied "don't understand question". It should be remembered that the US market is 1.6 times deeper than the European market, and therefore many US Mini-el buyers will purchase the Mini-el as a third or fourth transportation alternative.

FIGURE 9

CURB WEIGHT

Electric Vehicle Safety

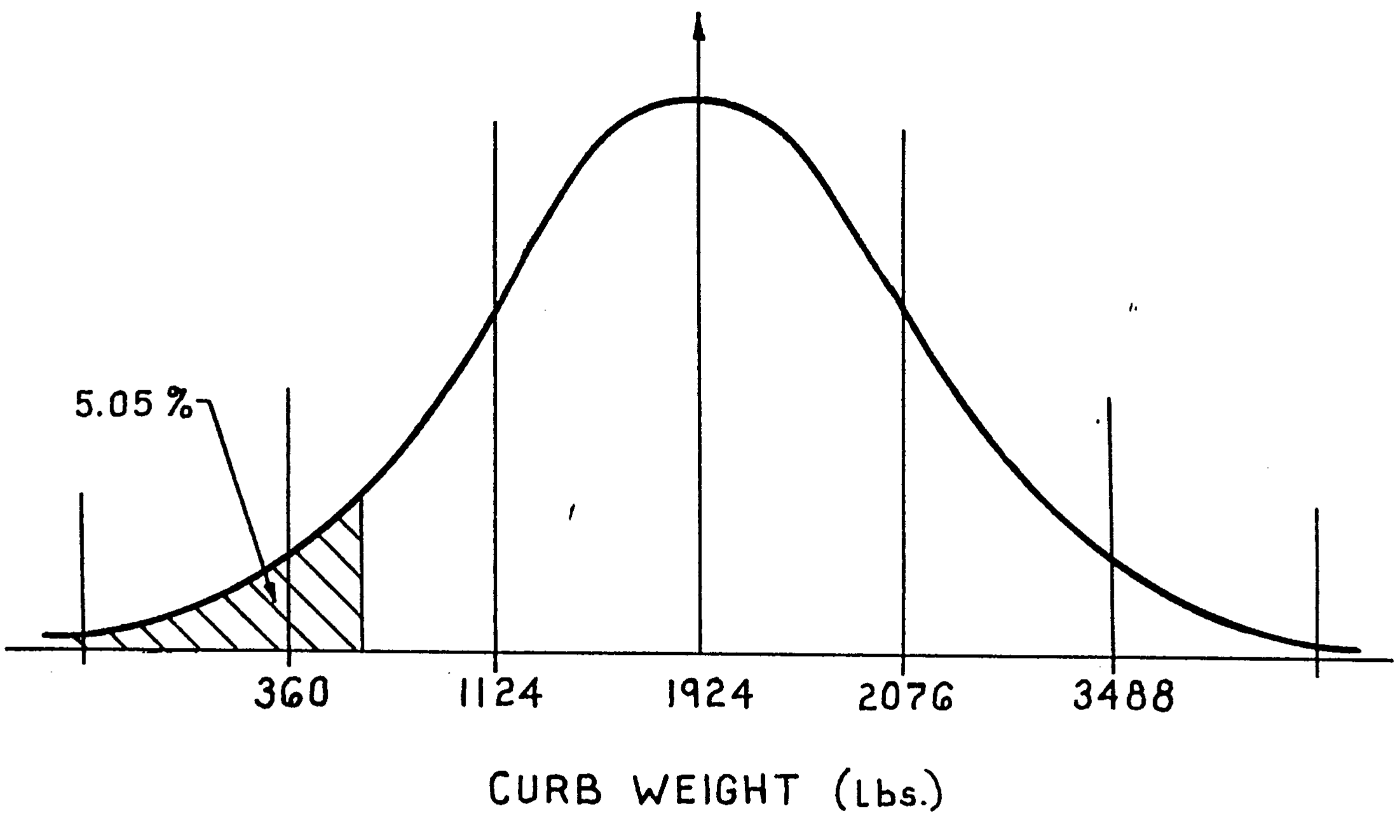


TABLE 6

Mini El Sales Forecast (Units)

	1993 Tot EVs 20,400	% of '98 29.6%	1994 Tot EVs 30,100	% of '98 43.6%	1995 Tot EVs 39,800	% of '98 57.7%	1996 Tot EVs 49,500	% of '98 71.7%	1997 Tot EVs 59,200	% of '98 85.8%	1998 Tot EVs 69,000	% of '98 100.0%
Sales Region	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
California	533	1,332	785	1,962	1,039	2,597	1,291	3,227	1,544	3,861	1,800	4,500
Arizona	4	24	7	35	9	46	11	57	13	69	15	80
Hawaii	3	18	4	26	6	35	7	43	9	51	10	60
Oregon	6	27	9	39	12	52	14	65	17	77	20	90
SubTotal	546	1,400	804	2,062	1,065	2,729	1,322	3,391	1,583	4,058	1,845	4,730
Connecticut	62	157	92	231	121	306	151	380	180	455	210	530
Massachusetts	102	258	150	379	199	502	247	624	296	746	345	870
New Jersey	81	323	120	475	159	629	197	782	236	935	275	1,090
New York	132	524	194	772	257	1,021	319	1,269	382	1,519	445	1,770
New Hampshire	12	50	17	74	23	98	29	122	34	146	40	170
Rhode Island	15	38	22	57	29	75	36	93	43	112	50	130
Vermont	6	21	9	31	12	40	14	50	17	60	20	70
Maine	10	41	15	61	20	81	25	100	30	120	35	140
Delaware	1	9	2	13	3	17	4	22	4	26	5	30
Maryland	12	62	17	92	23	121	29	151	34	180	40	210
Virginia	12	59	17	87	23	115	29	143	34	172	40	200
SubTotal,NorthEast	445	1,542	656	2,271	868	3,006	1,079	3,735	1,291	4,470	1,505	5,210
Florida	36	175	52	257	69	340	86	423	103	506	120	590
Grand Total	1,027	3,117	1,513	4,591	2,002	6,076	2,488	7,550	2,977	9,035	3,470	10,530

William R. Warf 6/26/92

Sales will not be related to the technical issues alone. Because of the strong political activities surrounding environmental issues, it is likely that sales may exceed the minimum estimates. It is also likely that EV's will increase in popularity because of the "fashionable statement" made by EV use. For these reasons, Sales should exceed the values predicted on purely technical issues in the early market place. These higher sales will be augmented by the limited availability of EV's, and by the low price of the Mini-el.

Table 7 reflects a final Sales Forecast for Mini-el USA. In 1993 and 1994 marketing efforts will be focused on California, where a political, social or fashionable statement motivation may contribute the most sales opprotunities.

During 1993, Sales are expected to be less than the middle of the forecast range, while in 1994 sales will exceed the maximum range predicted based on technical issues. The middle of the forecast range is used to estimate sales in 1995 through 1997.

Summary of Results

Average Mini-el Sales over the next six years are estimated as about 3000 units. The Mini-el USA factory must have a capacity to produce about 6800 units per year, to support maximum demand through 1995. If higher demand exists, a second similar factory should be constructed on the East Coast, or wherever the demand warrants.

The market is expected to grow very fast. It has been proposed that the distribution system incorporate significant demand and quality feedback features, to allow the factory build to match the actual demand, and to assure factory R&D and product improvement efforts match the market needs. If this is done there is a high probability of achieving larger customer acceptance and higher demand than predicted in this Market Estimate.

There is a significant lack of well developed products to fill the Electric Vehicle market right now. This is suggested by the survey results. The lack of products should enhance a quick penetration of the Electric Vehicle market by Mini-el USA.

It has been shown that one effect of Zero Emission Vehicle Sales requirements is to increase the public's awareness of Electric Vehicle capabilities and performance. The Mini-el will contribute to this awareness significantly in the early market place because of it's price and because of the quality of design and construction. The Mini-el represents an elegant engineering solution. The Mini-el makes much more sense than the Vans currently being tested by so many Utilities and Government Agencies.

TABLE 7

SALES FORECAST, Mini-El USA

YEAR	MAX SALES	MIN SALES	AVERAGE	FORECAST	NOTE
1993	1400	546	973	800	WEST COAST ONLY
1994	2062	804	1433	2450	WEST COAST 100-200 EAST COAST
1995	6076	2002	4039	4100	WEST + EAST
1996	7550	2488	5019	5000	WEST + EAST
1997	9035	2977	6006	6000	WEST + EAST
1998	10530	3470	7000	6000	NATIONWIDE

List of References:

1) Automotive News: May 29, 1991 issue; Published by Crane Communications

2) Ward's Automotive Reports, January 13, 1992 issue, Published by Ward's Communications

3) Quick Reference World Atlas, Copyright 1992, Rand McNally and Company

4) The Machine that Changed the World; Womack, Jones, and Roos, 1990, ISBN: 0-89256-350-8

5) Automobile Magazine, January 1992...referenced the Autofacts Inc. Report, $25,000, Autofacts: 215-429-9900

6) Impact of Battery-Powered Electric Vehicles on Air Quality in the Northeast States, Final Draft Report, Prepared for: NorthEast States for Coordinated Air Use Management (NESCAUM); 2/24/92... pages 20-27

7) Sacramento Municipal Utilities District (SMUD), Electric Vehicle Program, 1992 Program Plan

8) Dealernews, June 1992, Published by Advanstar Communications Inc. Cleveland, Ohio.

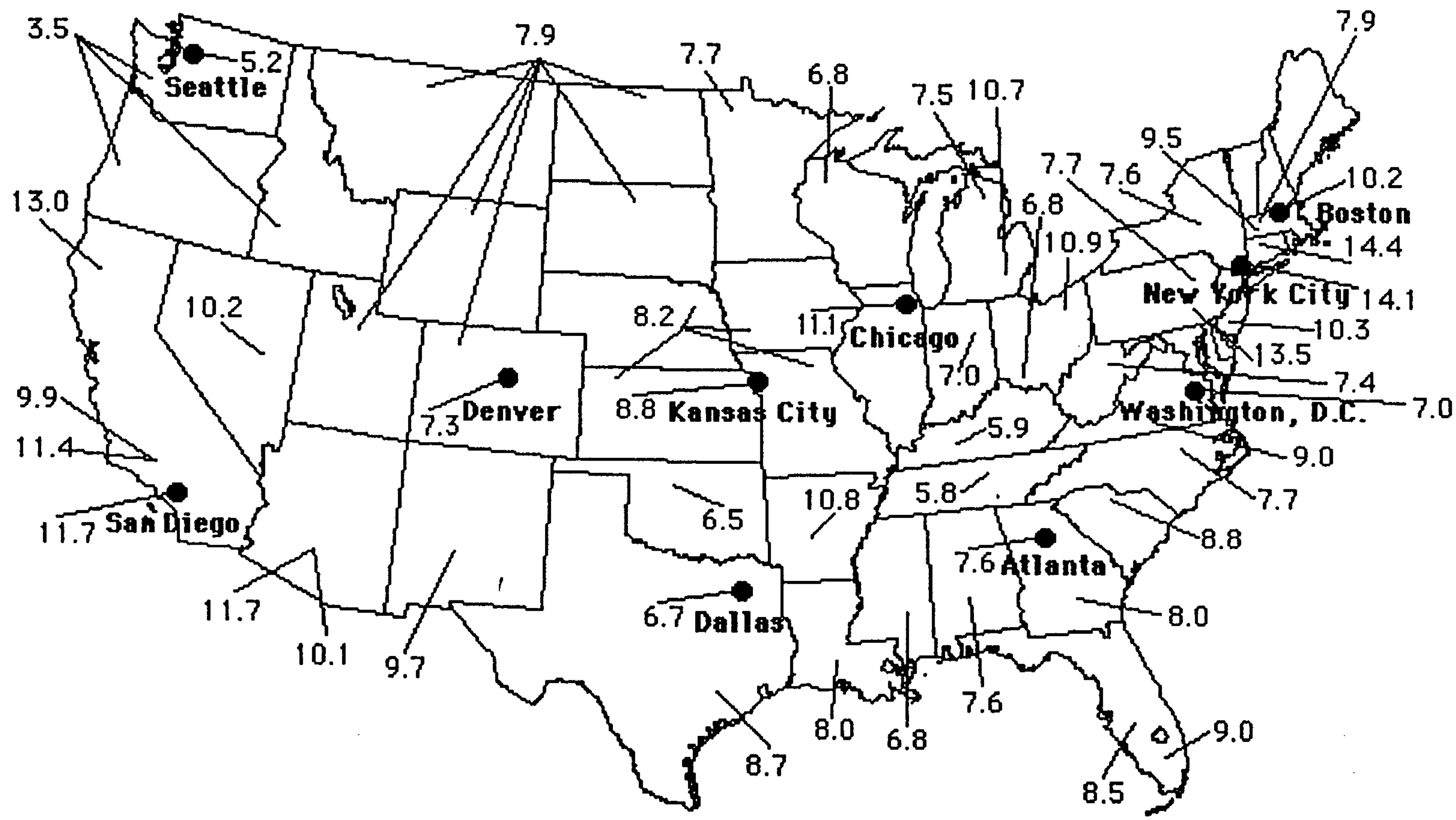
9) Juran's Quality Control Handbook, Fourth Edition, Published by McGraw Hill, 1988

10) The Entrepreneur's Manual, by R.M. White, Published by Chilton Book Company, 1977...page 322

11) 1992 World Almanac & Book of Facts, Pharos Books, NY,NY; 1991

Appendix 1
Average Residential Electric Rates

Cents / kilowatt hour



Appendix 2 Page 1 of 3

CityCom A/S
Haraldsvej 66
DK-8900 Randers

Smog problems of the cities have been heavily increasing during recent years as a consequence of the growing traffic concentration of gasoline-driven vehicles.

These smog problems have reached hazardous heights in many big cities.

The Danish company of CityCom A/S satisfies the needs for smog-free individual and local transport with the electrically driven vehicle mini-el City.

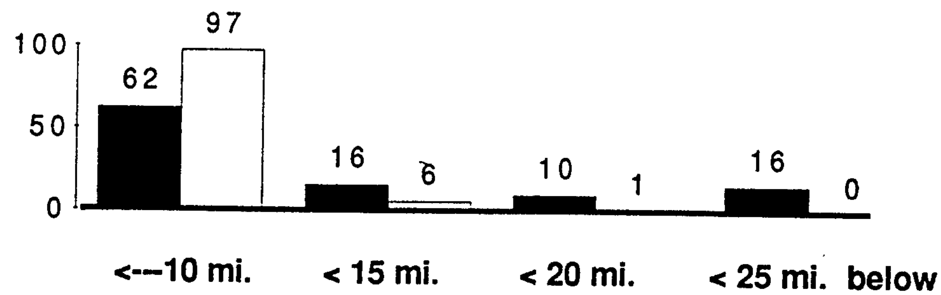
The mini-el City has a maximum speed of approximately 30 miles per hr. and a total range of up to 25 miles.

Questionnaire:

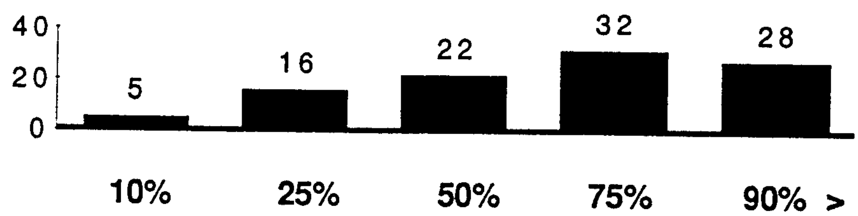
Analysis of 108 Respondents

1. How far do you have between home and work?

2. How far do you have to go to the shopping centre?

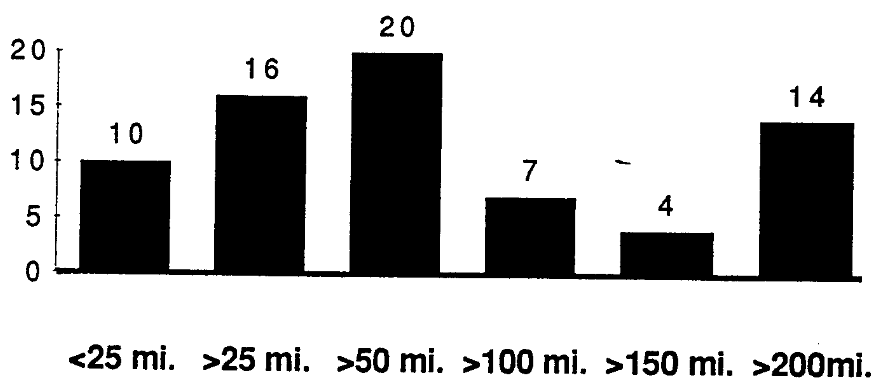


3. How much of the time do you drive alone?



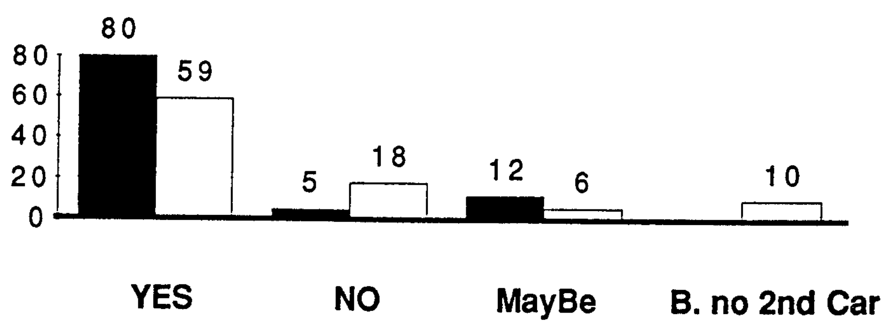
4. Minimum range between fill-ups of your second car?

(See separate graph p. 3 of 3)



A. Would you buy a mini-el City as your second vehicle?

B. Would you exchange your second car for a mini-el City?

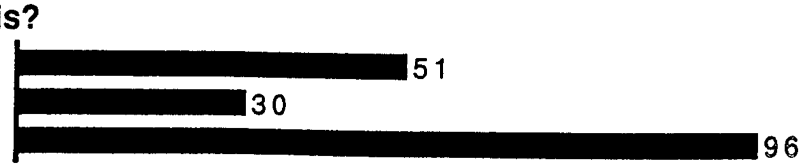


C. What is your motivation for this?

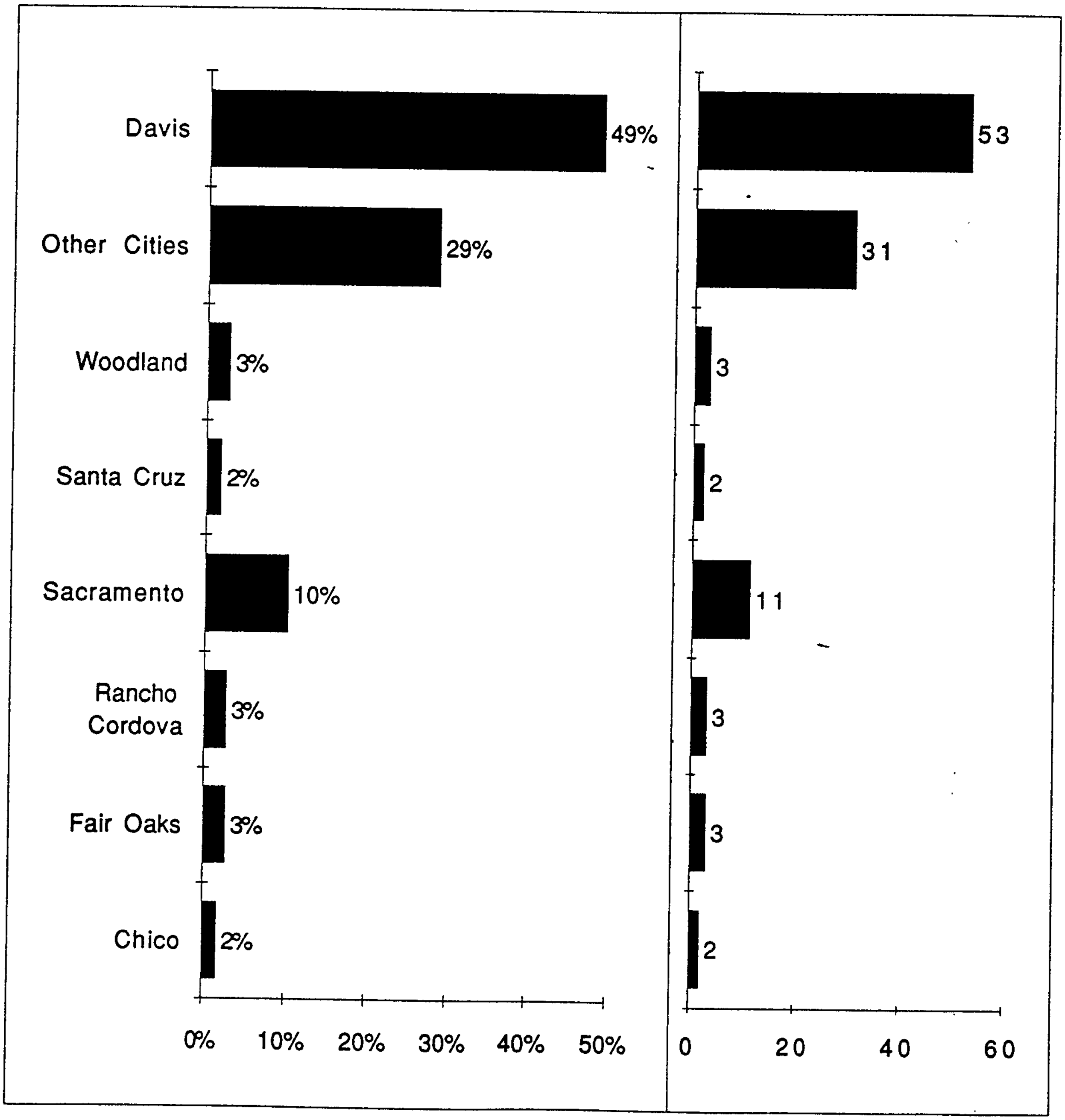
Transportation needs 47%

Easier parking 28%

Improve environment 89%



CityCom A/S
Haraldsvej 66
DK-8900 Randers



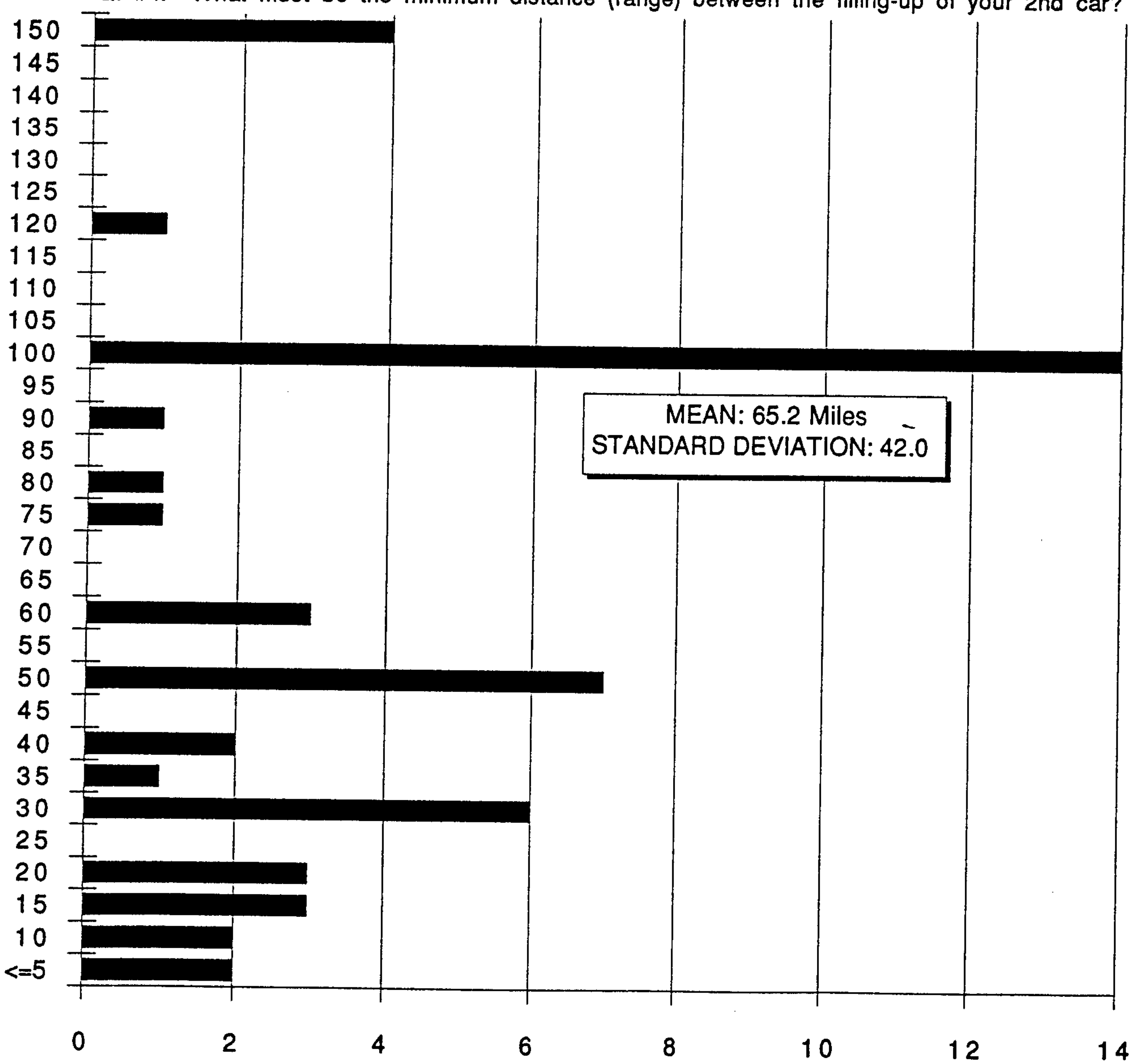
Population Profile

108 Respondents

CityCom A/S
Haraldsvej 66
DK-8900 Randers

Minimum Range

Q. #4. What must be the minimum distance (range) between the filling-up of your 2nd car?



William R. Warf 6/26/92

PACIFIC ELECTRIC VEHICLES

BUSINESS OFFICE
8500 WEYAND AVENUE
SACRAMENTO, CA 95828
FAX: 916-381-2189
PHONE: 916-381-3509

RESEARCH & DEVELOPMENT
190 FORD ROAD, SUITE 111
UKIAH, CA 95482
FAX 707-468-1460

LOS ANGELES SALES OFFICE
1613 CHELSEA ROAD, SUITE 244
SAN MARINO, CA 91108
FAX: 818-289-5946

September 29, 1993

Sacramento Municipal Utility District
Electric Transportation Department
PO Box 15830- MS 30 A
Sacramento, Ca. 95852-1830
Fax: 916-732-6839

Attention: Mr. Michael Wirsch

Subject: Data Management Plan, Service Record, and Inspection Report Submittal

Reference: Participation Agreement F-102; ARPA Grant MDA972-93-1-0025

Gentlemen:

Pacific Electric Vehicles is pleased to submit the attached Data Management Plan and Inspection Report format for your approval. I enclose in addition, the Service Record to be used by Drive Electric for your information. This submittal is in accordance with the referenced Participation Agreement.

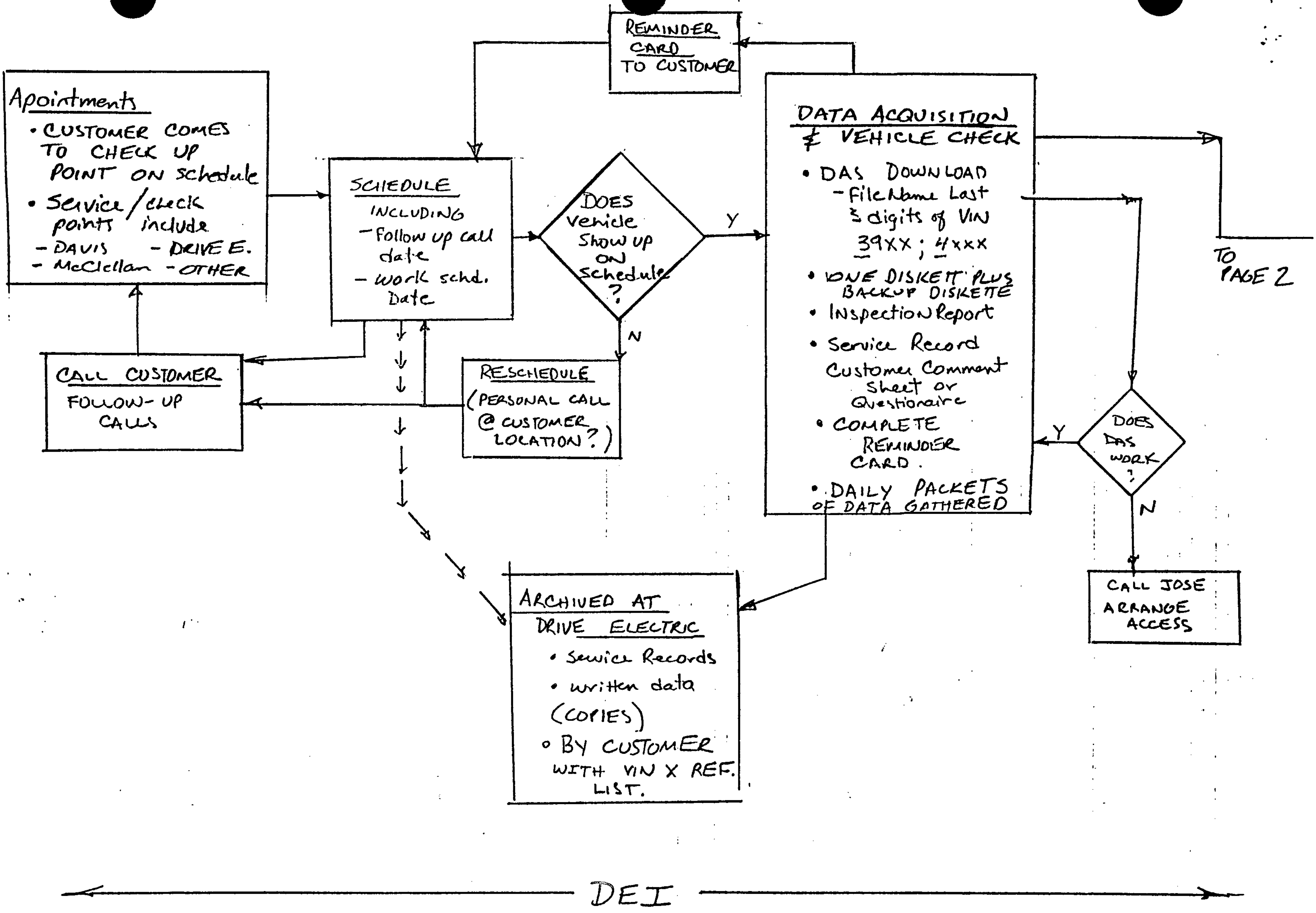
I note the Data Management Plan or Data Acquisition Process was developed by the NEV project team on 24 September, 1993.

I trust this submittal is satisfactory. Should you have questions or require additional information please contact me.

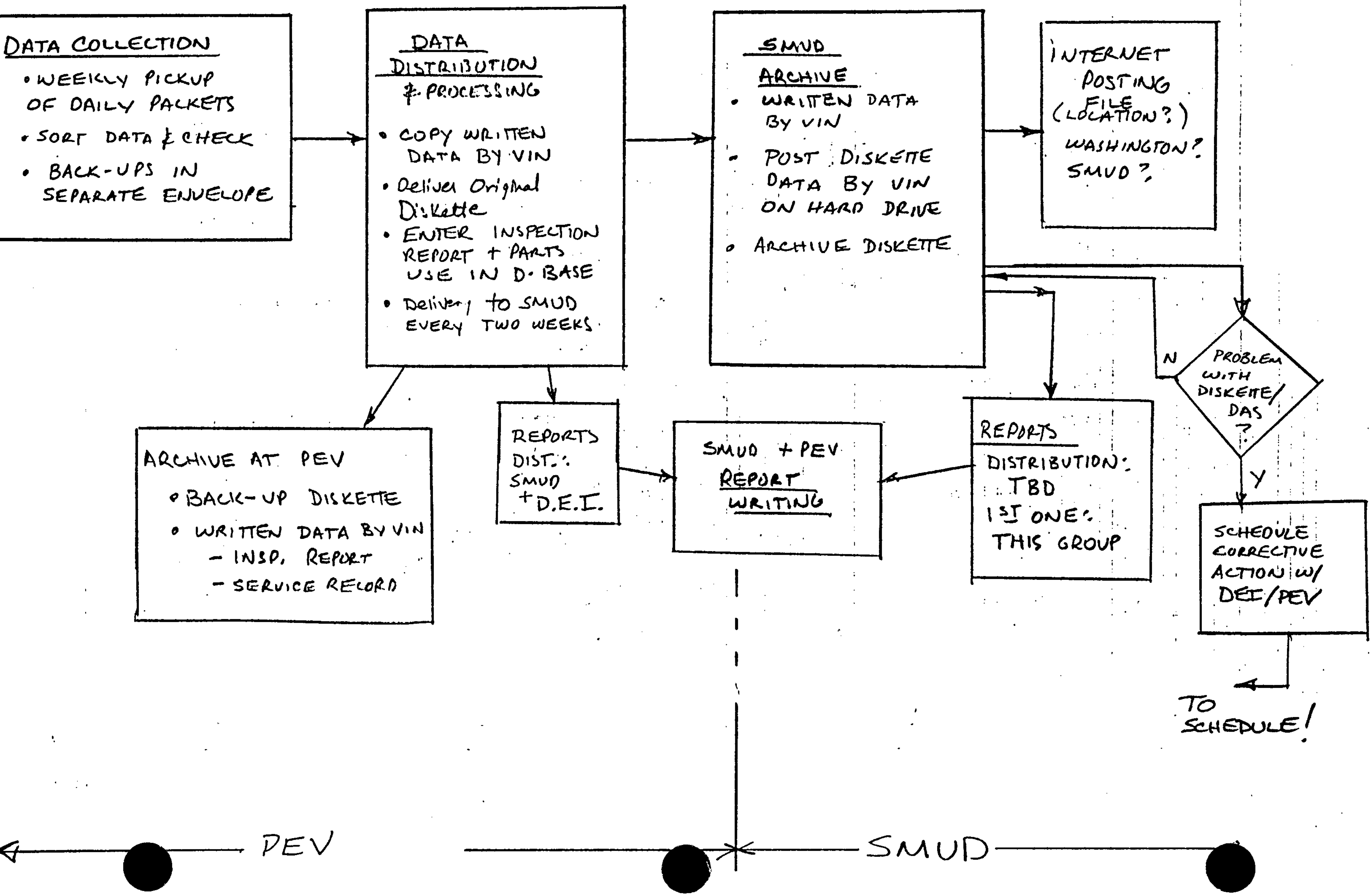
Regards,

W.R. Warf
Pacific Electric Vehicles
c: James Reede, SMUD Contract Administrator
Ruth MacDougall, SMUD Team Leader
Steve Rutter, SMUD Technical Leader
Barry Pearson, PEV

DATA CO LECTION PROCESS, PAGE 1 of



DATA COLLECTION PROCESS, PAGE 2 of 2



City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN=	UH5 MSE 04X PRS 03990
Date=	OCT. 20, 1993
data by=	WAWF

1. Plug in DAS to Computer while doing vehicle service!
Start data acquisition down load procedure.

2. Kilo-Watt hour meter reading= 15384

3. Odometer Reading= 200 Mi

4. Tire Pressure: As Found: fill all to 40-42 psig

	As Found	
Front:	30	WWW
left Rear	25	
Right Rear	26	

5. If batteries appear nearly full check specific gravity and Record:

Left Battery:	too low
Center Battery:	
Right Battery:	

6. Water Added to Batteries: (litres) 1.58 l

7. Battery Appearance: OK
   Battery Type SCS 225

8. Jack up front of vehicle and feel play in front wheel OK

9. Front Tire & Wheel true? note wear OK

10. Rear Wheel Condition, Inspect: OK

11. Lubricate Clutch Disc SLICK 50

12. Brake Fluid Level OK

13. Condition of Body, Lights OK

14. Check and Fill Window Washer OK WWW

15. After DAS down loaded, plug in diagnosis box, note voltage. 38V

15.a) Note State of Charge % 82% 100%

16. Plug In Charger and verify function OK

17. Drive Vehicle OK WWW 10/20/93   Service Record NONE

SAMPLE

SAMPLE

Pacific Electric Vehicles 916-381-3509

JOB NAME

PRODUCT 649-3 NEBS Inc., Groton, Mass. 01471. To Order PHONE TOLL FREE 1+800-225-6380

DRIVE ELECTRIC INC

REPAIR ORDER
WITH REMINDER CARD

NEV PROJECT

YEAR	MAKE	MODEL	LIC. NO.
93	City-el		
VEHICLE I.D. NO.		**MILEAGE**	**DATE**
503344		583	10/20/93
SERVICES PERFORMED			
DUE BACK FOR SERVICE			
DATE	**OR**	**MILEAGE**	
11/20/93			

NAME: TIM TOWNSEND
ADDRESS: 320 E STREET
CITY: DAVIS STATE: CA ZIP: 95616
PHONE (HOME): 757 1514 (WORK): 753 0795

- A SIMPLE TUNE-UP, DONE ON TIME, KEEPS AN ENGINE OPERATING EFFICIENTLY.
- TYPICAL CITY DRIVING REQUIRES AN OIL CHANGE EVERY 3000 MILES.
- TIRE ROTATION TIME IS AN EXCELLENT REMINDER THAT IT'S TIME FOR A BRAKE INSPECTION.

DESCRIPTION OF WORK	AMOUNT
☐ CHANGE OIL ☐ OIL FILTER ☐ TUNE-UP ☐ LUBE	
Replaced Hub Cap Studs	No charge
(5 MINUTES)	

QTY.	PART NO. AND DESCRIPTION	PRICE	
3	70.103	3.42	10.26
6	261.004	.17	1.02

ORDER WRITTEN BY: WAM
☐ CASH ☐ CHECK ☐ MC ☐ VISA

I hereby authorize the above repair work to be done along with the necessary materials. You and your employees may operate above vehicle for purposes of testing, inspection, or delivery at my risk. An express mechanics lien is acknowledged on above vehicle to secure the amount of repairs thereto. It is also understood that you will not be held responsible for loss or damage to cars or articles left in cars in case of fire, theft or any other cause beyond your control.

SIGNATURE
X

TOTAL PARTS	11.28
TOTAL LABOR	Ø
SUB-TOTAL	11.28
TAX	.81
TOTAL	12.09

1257 Thank You

SAMPLE

PRODUCT 649-3 NEBS Inc., Groton, Mass. 01471. To Order PHONE TOLL FREE 1+800-225-6380

PACIFIC ELECTRIC VEHICLES

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8500 WEYAND AVENUE
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1613 CHELSEA ROAD, SUITE 244
SAN MARINO, CA 91108
FAX: 818-289-5946

Meeting Notes, Data Collection Process, 24 September, 1993 www 9/29/93

A meeting was held at SMUD to develop the data management process to be used in execution of the Neighborhood Electric Vehicle Project.

Meeting Attendees:
Sal Caravello, George Broad of Drive Electric
Jose Baer, (and Ruth MacDougall part time) of SMUD
Bill Warf of PEV
Henning Bitsch

The attached Data Collection Process outline describes the Data Management Process. It is noted that the methods of Acquisition, Archival, Distribution, and analysis are provided in this process management outline.

Action Items:
1. Sal: Make a customer comment sheet and a questionnaire for distribution to the group for comments
2. Bill: Make a VIN spread sheet, Excel, and provide a copy to George and Jose
3. George and Bill, work on database for entering and retrieving Inspection Report and Service Record data, as well as customer to VIN cross reference
4. Bill, Provide lease language regarding customer cooperation with data collection, copy to group
5. Jose, Work on Laptop computer and other data acquisition equipment.

Other Discussion Items:
a) unloading of container is PEV responsibility. Plan to be communicated to all. As of now container is destined to PEV at 8500 Weyand Ave.
b) Installation of Batteries and DAS...Batteries need to be installed after unloading vehicles from container such that the vehicles can be moved. Location of other work may be at PEV, or DEI...this is to be determined.
c) Rework to meet DOT requirements is required, and will be accomplished during preparation for delivery. This is at present PEV's responsibility.

Next Meeting: 9/30/93 at 2 PM, at Drive Electric...Training and equipment requirements for down loading DAS.

City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN= ____________________

Date= ____________________

data by= ____________________

1. Plug in DAS to Computer while doing vehicle service!
Start data acquisition down load procedure.

2. Kilo-Watt hour meter reading= ____________________

3. Odometer Reading= ____________________

4. Tire Pressure: As Found: fill all to 40-42 psig

Front: ____________________

left Rear ____________________

Right Rear ____________________

5. If batteries appear nearly full check specific gravity and Record:

Left Battery: ____________________

Center Battery: ____________________

Right Battery: ____________________

6. Water Added to Batteries: (litres) ____________________

7. Battery Appearance: ____________________

Battery Type ____________________

8. Jack up front of vehicle and feel play in front wheel ____________________

9. Front Tire & Wheel true? note wear ____________________

10. Rear Wheel Condition, Inspect: ____________________

11. Lubricate Clutch Disc ____________________

12. Brake Fluid Level ____________________

13. Condition of Body, Lights ____________________

14. Check and Fill Window Washer ____________________

15. After DAS down loaded, plug in diagnosis box, note voltage. ____________________

15.a) Note State of Charge %   82%   100%

16. Plug In Charger and verify function ____________________

17. Drive Vehicle   Service Record

Test Report, Charger Efficiency on the City-el Electric Vehicle

30 March, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: William R. Warf
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

TEST REPORT: City-el Charger Efficiency

Prepared by: W.R. Warf, Pacific Electric Vehicles, 3/30/94

Purpose: The purpose of this report is to document a test of the City-el charger performed on 3/25/94. The purpose of the test was to estimate the efficiency of the City-el charger for comparison to other chargers which might be considered for a Neighborhood Electric Vehicle (NEV), and to benchmark the efficiency of the charger as a part of the overall vehicle system.

Scope: This report discusses the test set-up, measuring equipment, and the test procedure. Results are compared to a similar charger test performed on 9/5/93. Conclusions and additional work which needs to be done to confirm the results are provided.

Conclusions: The City-el charger delivers about 64% of the 120 VAC energy from the plug to the batteries. Instantaneous power use efficiencies range from 56% to 67% during the main and gassing portions of the charge cycle. During the holding charge, where the charger draws about 50 Watts from the AC outlet, the charger efficiency is about 22%. The measurement techniques used can not be assumed to be better than about +/- 5%, or 10 % total error. Efficiency as used in this report means DC power delivered to the battery divided by AC power withdrawn through the plug - outlet. The overall efficiency was calculated based on a time weighted average, or calculated DC Watt-hours divided by calculated AC Watt hours.

Additional work needs to be done to verify the following:

1. The Hydria Watt-hour meter was used to record Watt-hours, Watts, and time. While the power reading in Watts was verified by Jose Baer in a previous test on a prototype of the meters presently in use, there have been no checks on the timer or the Watt-hour meter. In addition, the Hydria meter is mounted on top of the main transformer, and may give different readings because of this mounting. Are the readings taken from the Hydria reliable? A test needs to be done, and perhaps a calibration. It is noted that the Energy use calculated from the Power and Time readings on the Hydria do not match the kW-hour counter, as shown in CHGT0325.XLS chart 7.

2. The analysis of the test data taken during this report assumes that DC Amps and Volts can be multiplied directly to calculate DC Watts from the charger. Since this is only valid if the current and voltage signals are in phase, an oscilloscope test needs to be performed to verify these values are in phase, or determine the phase angle for different parts of the charge cycle.

3. It would be useful to measure the Charge Transformer and the charger board separately to estimate the efficiency of these physically separate components. The equipment needed for a meaningful test may not be available during this project, however.

Test Set-up and Initial Conditions:
The test was conducted at PEV. City-el S/N 4135 was driven to 25 miles to Davis on 3/24/94, and, after charging for 3.5 hours, driven 25 miles back to Sacramento. This vehicle had 260.8 miles on the odometer at the conclusion of the drive, and the start of the charger test. The last dot on the capacity gage display went out about 2 miles before the end of the trip. The charge cycle in Davis was interrupted, meaning only the main charge portion was complete, (10 dots on capacity gage). The charger therefore set the ETG light, and did a long gassing cycle. Batteries installed in the vehicle were Trojan 30XH. DC energy use was about 1630 DC Watt hours for each leg of the trip to and from Davis as measured by the Cruising Equipment Watt-hour meter.

The charge test was commenced on 3/24/94 after instrumentation was installed. The charge test was interrupted by un-plugging the charge transformer from the outlet after 2.13 hours of charging on 3/24 at about 6 PM. The test was resumed on 3/25/94 in the morning. The interruption was necessary to assure complete data recording. The charge was interrupted again for the same reason by un-plugging after 6.95 hours more charging.

To make the measurements, a DC Voltmeter was connected to the batteries, and a Fluke 21 used to measure the charge shunt voltage through the connections provided in the diagnosis box. The Hydria Watt-hour meter installed on the charger was used for time, energy, and power. In addition, a Cruising equipment meter was used to provide another DC Watt-hour reading for comparison to the calculated value. This was done to evaluate the accuracy of the Cruising equipment meter. All data was recorded manually, and is shown in the attached table, before analysis.

Test Equipment:

1. Hydria Watt Hour meter, ~~S/N~~ MODEL ST2400A, installed on Charge Transformer S/N 0060, SMUD tag 4.

2. Sensitive Research Instrument Co. DC reference voltmeter, Model C, S/N 942135.

3. Fluke Model 21 series II multimeter, S/N 58570412. (To measure millivolts across a 3.3 mV/ Amp shunt in the vehicle.)

Data Analysis:

All of the data from the test record was entered into a spread sheet program for analysis. This spread sheet is labeled CHGT0325.XLS, and is attached. The interruptions of the charge cycle were smoothed by adding time and AC kW-h values from the previous part to the subsequent values. Each entry is explained as follows (headings match spread sheet column labels):

C. Hour: Recorded from the Hydria meter.

D. AC kW-hour: read directly from the display. It is noted that the counter values were recorded as 157,689 before the test and 163,934 after, which agrees reasonably well with the 6.26 kW-hour value recorded from the display, but does not agree with the AC kW-hour value calculated in K.

E. AC W, recorded from the display on the Hydria meter.

F. Volts, recorded form the Sensitive Research Volt meter at the battery connections to the vehicle.

G. Shunt: millivolts across the vehicle charge shunt R-2, with the Fluke 21.

H. Amps: calculated by dividing the voltage drop across the shunt R-2 by 3.3 mV/Amp.

I. DC W: calculated by multiplying DC Volts in F. by DC amps in H.

J. Efficiency: calculated by dividing DCW in I. by AC W in E.

K. AC Wh Calc. calculated by multiplying the time for the row by the AC Watts recorded in E, and adding the above AC W-h value to realize a cumulative figure.

F. DC Wh Calcd. : calculated by multiplying the time for the row by the DC Watts calculated in I, and adding the above DC W-h value to realize a cumulative figure. Note that the Cruising Equipment meter read 3.29 DC Watt hours after the charge, which agrees well with the 3.27 DC Watt hour value calculated.

Tables and graphs:

The following graphs are attached to this report.

CHGT0325.XLS chart 5, which shows DC Volts, DC Amps, and efficiency for the test. Note the equalizing charge lasted about 7.8 hours after a 3.68 hour main charge to 43.25 volts. The hold charge was terminated by unplugging at 12.52 hours, when the AC Watt value repeated.

CHGT0325.XLS chart 3, which shows AC power and DC power plotted versus time.

CHGT0325.XLS chart 7, which shows AC energy recorded from the Hydria display, compared to calculated AC and DC energy. Note the display value is higher than the calculated value. This is the variation which suggests some additional testing be accomplished on the Hydria as installed. It is noted that the data acquisition system appears to rely on this counter for recording of AC power during the charge cycles.

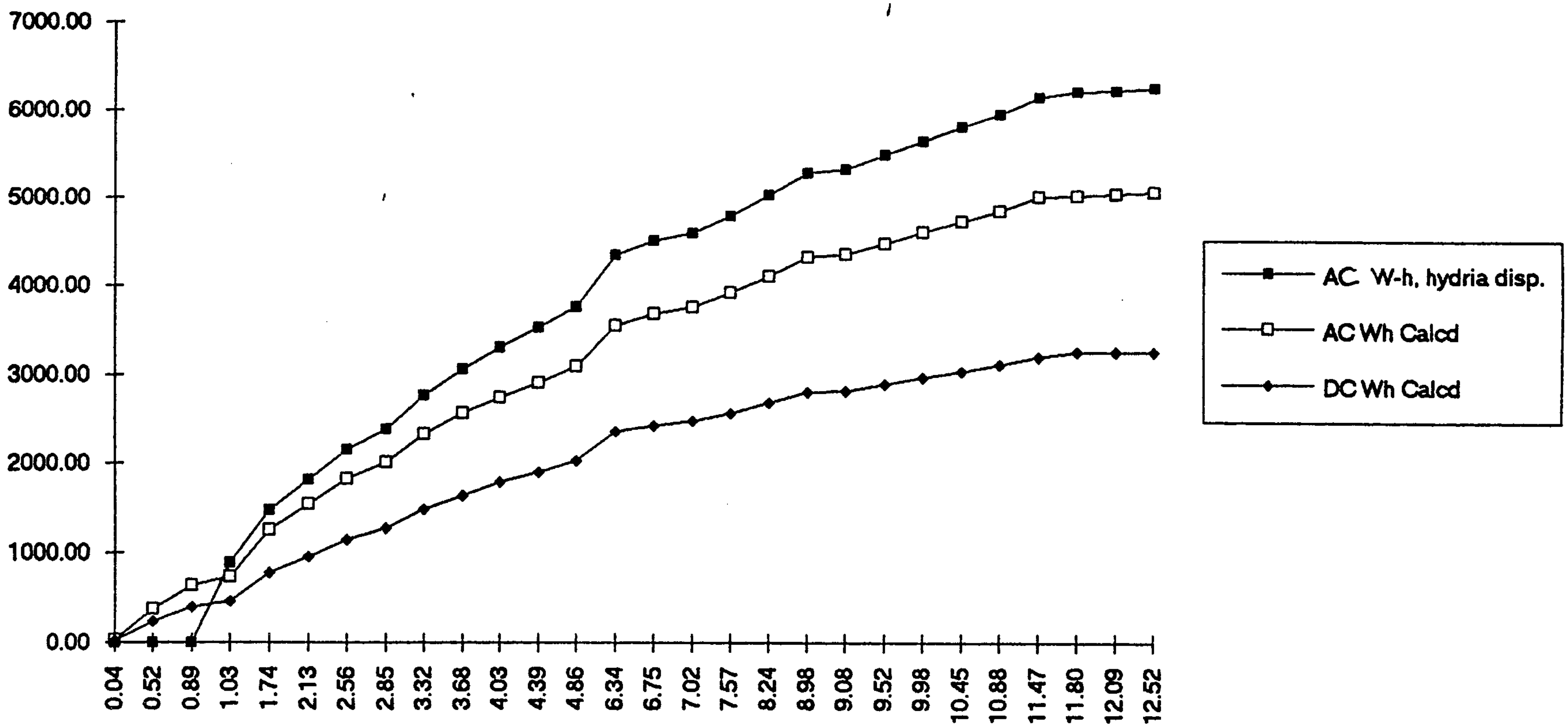
In addition I have attached charts from the previous charge test conducted on 9/5/93 for comparison. This previous test was performed with similar equipment, and agrees reasonably well with the present test. The following are attached.

CHGTEST.XLS Chart 1, labeled Charge Test of 9/5/93, AC Power and DC Power versus time.

CHGTEST.XLS Chart 2, which shows efficiency, DC voltage and amperage. Note that the batteries were fully discharged to one dot showing on the capacity gage before the 9/5/93 test. It is interesting to note the total charge time in the 9/5 test was only 8 hours.

A table of data used to graph the 9/5/93 test is also attached. The full test report is available upon request.

Charge Test of 3/25/94, measured and calculated W-h vs Time (hours)



Charger efficiency test on City-el 4135

Start:
Full discharge
T = 0
Charge shunt = 3.3 mV/A

End of gassing:
kWh meter: 163934
kWh CE meter: 1.94

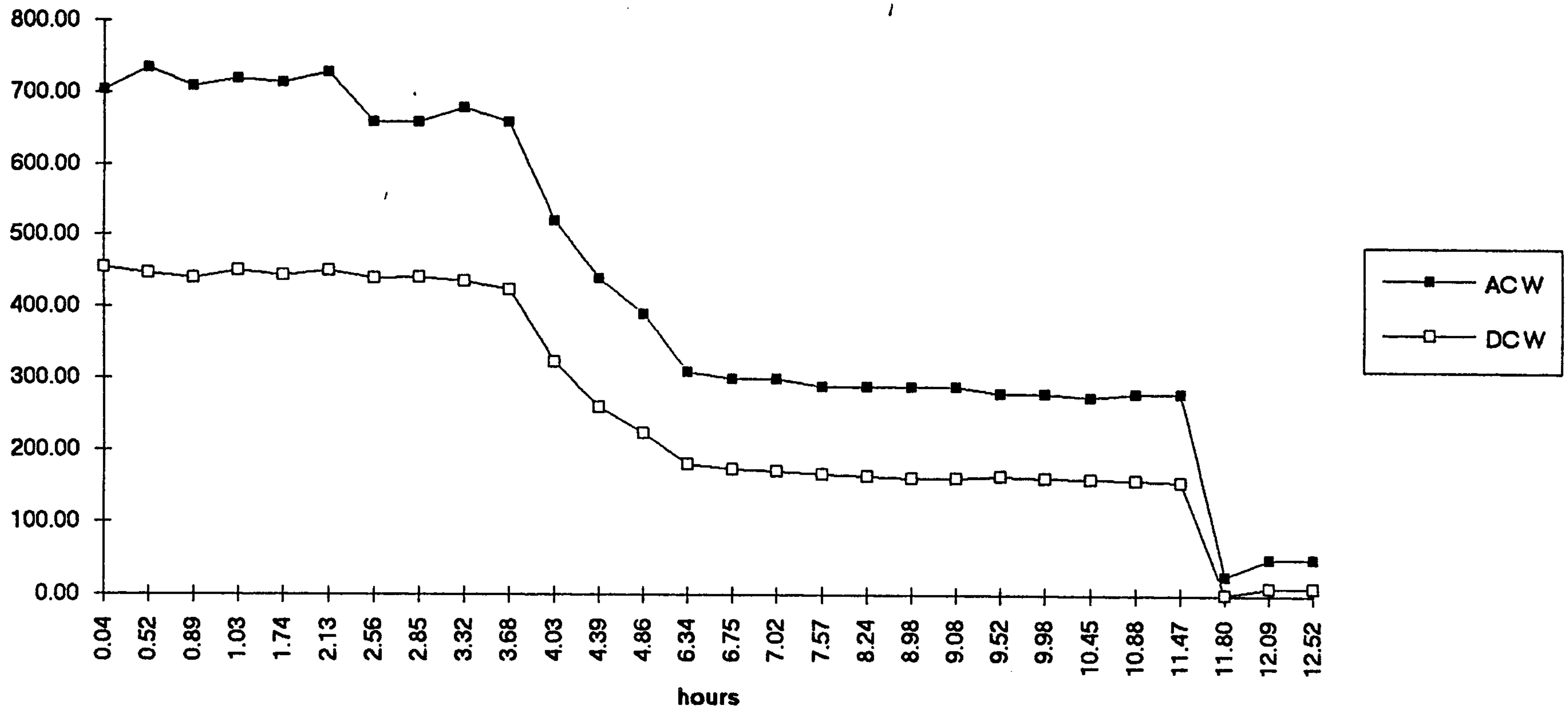
Bill, I took the liberty of entering the data into a spread sheet so that when it was faxed you could still read it. The originals will be on your desk here at PEV. I have double checked my data entry to ensure that these are the correct numbers.

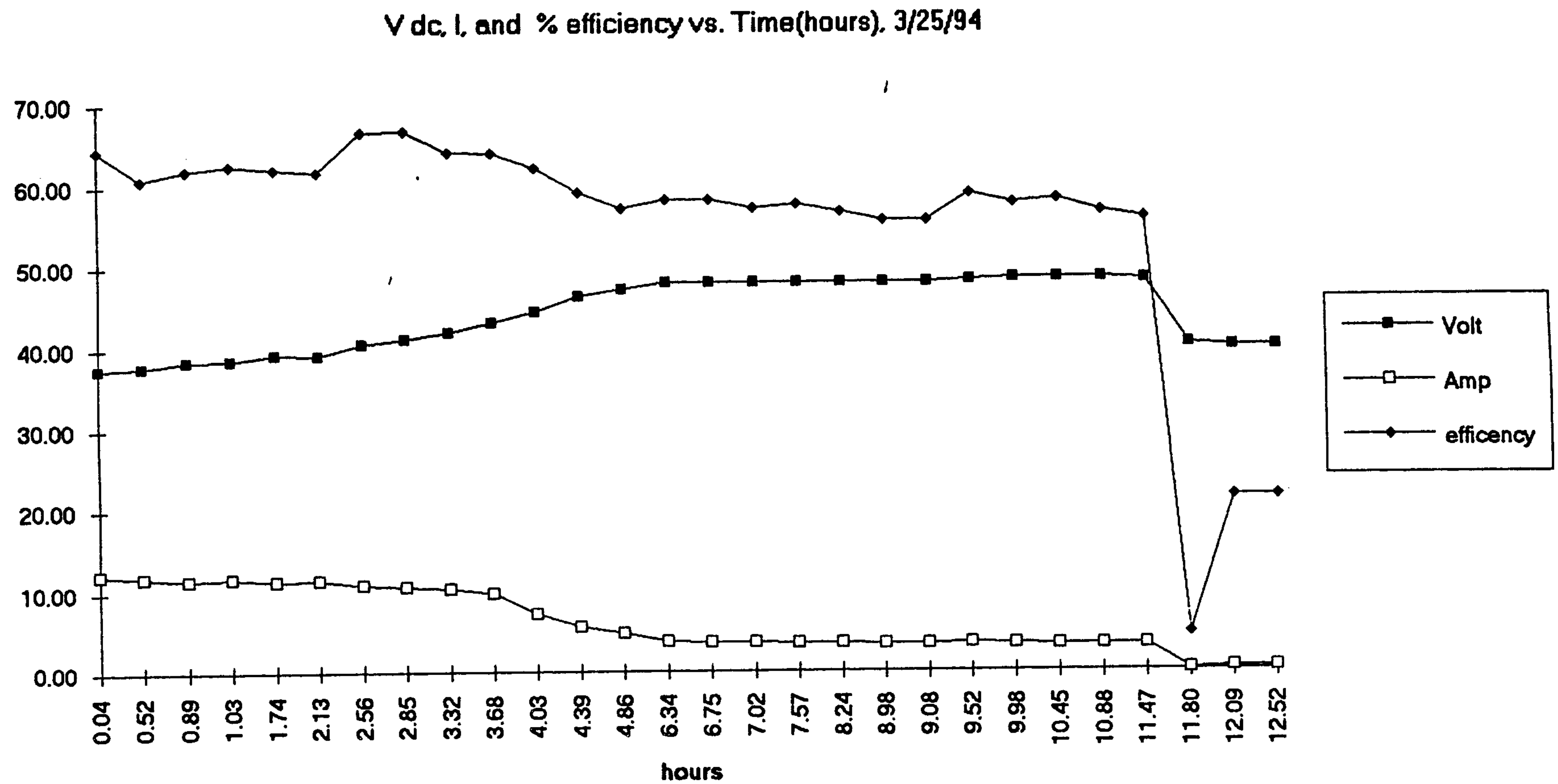
Hours	kWh	AC W	V DC	mV	CE I
0.04		0.705	37.5	40	12
0.52		0.735	37.75	38.1	12
0.89		0.71	38.5	37.75	11.5
1.03	0.89	0.72	38.6	38.5	12
1.74	1.48	0.715	39.3	37.3	12
2.13	1.82	0.73	39.25	37.9	12
Charge Interrupted					
0.43	0.33	0.66	40.6	35.8	11
0.72	0.57	0.66	41.2	35.3	11
1.19	0.95	0.68	42	34.3	10
1.55	1.24	0.66	43.25	32.3	10
1.9	1.49	0.52	44.5	24	8
2.26	1.7	0.44	46.4	18.5	6
2.73	1.93	0.39	47.2	15.6	5
4.21	2.53	0.31	48	12.4	4
4.62	2.69	0.3	48	12	4
4.89	2.78	0.3	48	11.8	4
5.44	2.98	0.29	48	11.5	4
6.11	3.22	0.29	48	11.3	4
6.85	3.47	0.29	48	11.1	4
6.95	3.51	0.29	48	11.1	4
Charge Interrupted					
0.44	0.17	0.28	48.2	11.3	4
0.9	0.32	0.28	48.5	11	3
1.37	0.48	0.275	48.5	10.9	3
1.8	0.63	0.28	48.5	10.8	3
2.39	0.83	0.28	48.25	10.7	3.5
2.72	0.89	0.026	40.4	0.1	0
3.01	0.9	0.0505	40	0.9	0
3.44	0.93	0.0505	40	0.9	0

	Hydria	Hydria	Hydria	Ref V meter	Fluke		F * H	I/E		
	C	D	E	F	G	H	I	J	K	L
1	Hour	AC kW-h	AC W	Volt	Shunt	Amp	DC W	eff.	AC Wh Calc	DC Wh Calcd
2	0.04		705.00	37.50	40.00	12.12	454.55	64%	28.20	18.18
3	0.52		735.00	37.75	39.10	11.85	447.28	61%	381.00	236.36
4	0.89		710.00	38.50	37.75	11.44	440.42	62%	643.70	401.86
5	1.03	0.89	720.00	38.60	38.50	11.67	450.33	63%	744.50	463.52
6	1.74	1.48	715.00	39.30	37.30	11.30	444.21	62%	1252.15	783.25
7	2.13	1.82	730.00	39.25	37.90	11.48	450.78	62%	1536.85	956.49
8	2.56	2.15	660.00	40.60	35.80	10.85	440.45	67%	1820.65	1150.33
9	2.85	2.39	660.00	41.20	35.30	10.70	440.72	67%	2012.05	1278.06
10	3.32	2.77	680.00	42.00	34.30	10.39	436.55	64%	2331.65	1485.20
11	3.68	3.06	660.00	43.25	32.30	9.79	423.33	64%	2569.25	1642.35
12	4.03	3.31	520.00	44.50	24.00	7.27	323.64	62%	2751.25	1790.52
13	4.39	3.52	440.00	46.40	18.50	5.61	260.12	59%	2909.65	1907.03
14	4.86	3.75	390.00	47.20	15.60	4.73	223.13	57%	3092.95	2029.28
15	6.34	4.35	310.00	48.00	12.40	3.76	180.36	58%	3551.75	2359.51
16	6.75	4.51	300.00	48.00	12.00	3.64	174.55	58%	3674.75	2433.46
17	7.02	4.60	300.00	48.00	11.80	3.58	171.64	57%	3755.75	2480.59
18	7.57	4.80	290.00	48.00	11.50	3.48	167.27	58%	3915.25	2574.99
19	8.24	5.04	290.00	48.00	11.30	3.42	164.36	57%	4109.55	2687.06
20	8.98	5.29	290.00	48.00	11.10	3.36	161.45	56%	4324.15	2808.69
21	9.08	5.33	290.00	48.00	11.10	3.36	161.45	56%	4353.15	2824.83
22	9.52	5.50	280.00	48.20	11.30	3.42	165.05	59%	4476.35	2895.87
23	9.98	5.65	280.00	48.50	11.00	3.33	161.67	58%	4605.15	2971.80
24	10.45	5.81	275.00	48.50	10.90	3.30	160.20	58%	4734.40	3047.78
25	10.88	5.96	280.00	48.50	10.80	3.27	158.73	57%	4854.80	3116.66
26	11.47	6.16	280.00	48.25	10.70	3.24	156.45	56%	5020.00	3210.31
27	11.80	6.22	26.00	40.40	0.10	0.03	1.22	5%	5028.58	3261.94
28	12.09	6.23	50.50	40.00	0.90	0.27	10.91	22%	5043.23	3262.30
29	12.52	6.26	50.50	40.00	0.90	0.27	10.91	22%	5064.94	3266.99
30	Hour	AC kW-h	AC W	Volt	Shunt	Amp	DC W	eff.		
31	NOTES:									
32	1. kW-h AC calculated by ((C3-C2)*(E3))+L2									
33	2. DC W-h calculated same way as AC									

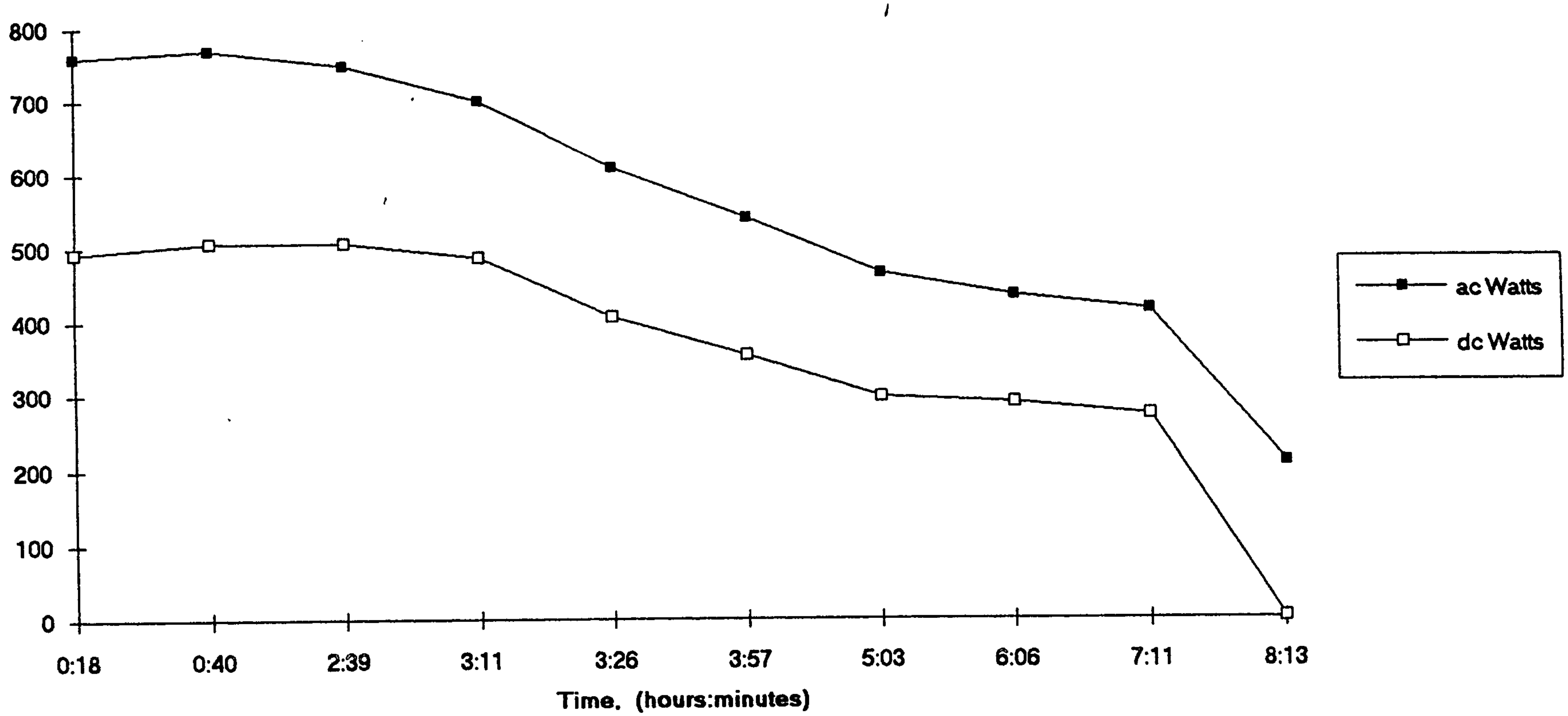
Q ⇒ why D ≠ K ?

ac Watts and dc Watts versus time (hours), charge test of 3/25/94

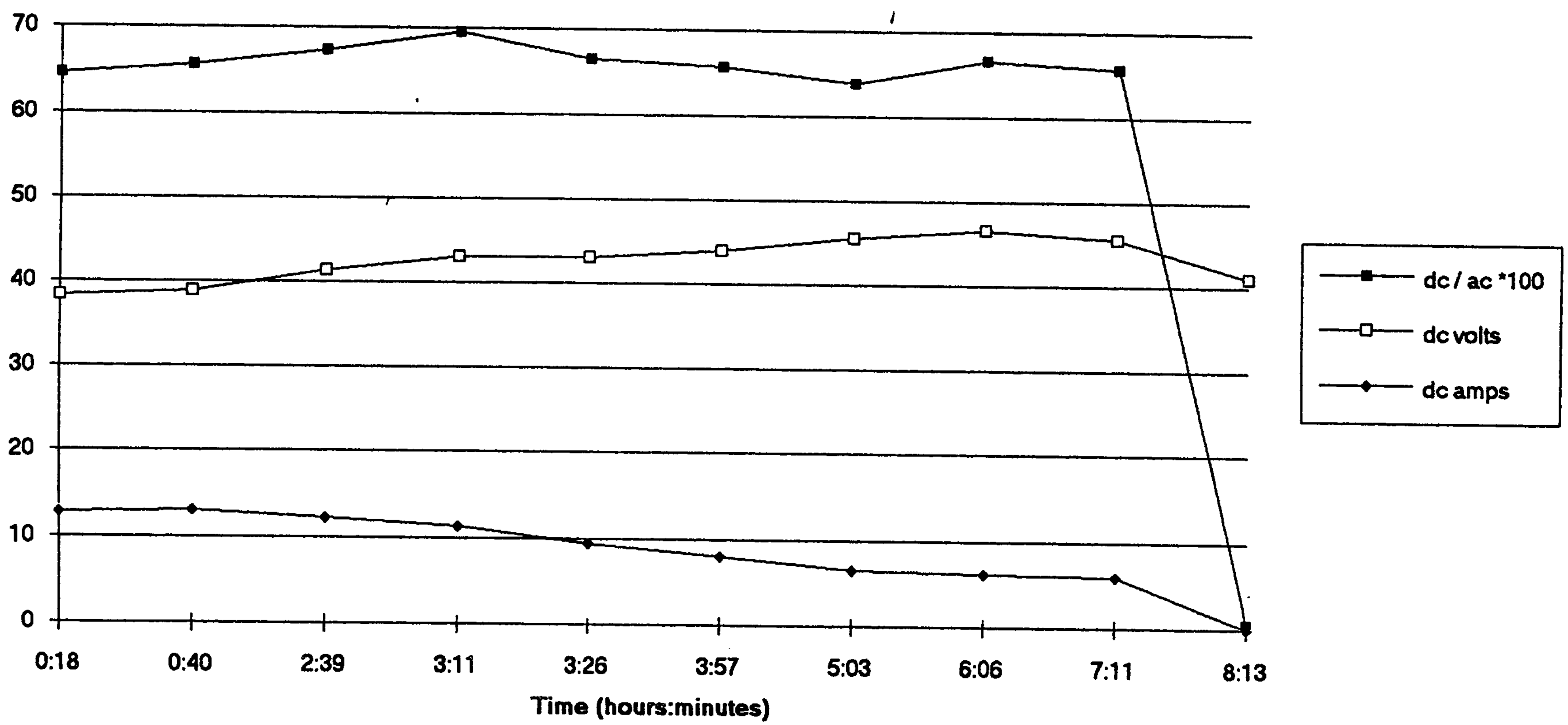



V dc, I, and % efficiency vs. Time(hours), 3/25/94
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.04
0.52
0.89
1.03
1.74
2.13
2.56
2.85
3.32
3.68
4.03
4.39
4.86
6.34
6.75
7.02
7.57
8.24
8.98
9.08
9.52
9.98
10.45
10.88
11.47
11.80
12.09
12.52
hours
Volt
Amp
efficency

Charge Test of 9/5/93, City-el



Charge Test of 9/5/93, City-el



Charge Test on 9/5/93, data, city-el

ac Watts	dc Watts	time (hours:minutes)	dc / ac *100	dc volts	dc amps
760	492	0:18	65	38.30	12.84
770	505	0:40	66	38.82	13.02
750	506	2:39	67	41.30	12.24
700	486	3:11	69	43.00	11.31
610	406	3:26	67	43.00	9.45
540	355	3:57	66	44.00	8.07
465	298	5:03	64	45.50	6.54
435	290	6:06	67	46.50	6.24
415	273	7:11	66	45.50	6.00
210	1	8:13	1	41.00	0.03

Safety Review Summary

5 April, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: William R. Warf
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

5 April, 1994

Safety Review Summary Report

Abstract: City-el drivers will utilize the vehicle safely if they are well trained regarding the capabilities of the vehicle. In addition to being thoroughly briefed about vehicle dynamics, operators should be fully briefed on the safety interlocks furnished in the vehicle, and in charging safety.

Purpose and Scope: The purpose of this report is to document the safety review which was performed and the training session which was developed to help assure the safety of vehicle users involved with the NEV Project. This document summarizes the Safety Review activities accomplished and the resulting safety training class.

Safety Review Summary:
A Safety Review was undertaken in late October 1993, following a roll over accident which occurred in one of the SMUD owned vehicles while being demonstrated at Drive Electric Inc. The review was based on all experience with the vehicles to date, and based on the manufacturer's recommendations for safe operation.

The safety review resulted in a training class which was discussed and finalized on November 10, 1994 at Pacific EV. Attending the meeting were PEV, Drive Electric, SMUD, and McClellan AFB personnel.

The training class is used to train and license all City-el drivers at McClellan. The class is also used to train private customers. The class notes which are provided during the session are attached. All drivers are required to wear a motorcycle helmet under California Motor Vehicle Code regulations. All drivers are advised of the weight limitations of the vehicle, and of it's handling properties. Charging safety is also discussed. Interlocks which may prevent driving the vehicle are covered, including the Canopy Switch which prevents driving with the Canopy up, and the charger interlock which prevents driving while plugged in. Each user is shown how to adjust the mirrors and the seat.

The safety review also resulted in each vehicle being fitted with a Warning Label, which advises operators to wear a helmet and that cornering at too high a speed may result in vehicle roll over.

All vehicles at McClellan are fitted with bicycle flags and driving is limited in inclement weather.

The first training session at McClellan on 23 November was attended by base safety personnel, who were satisfied with the content of the training course. Since the course was developed, 210 base personnel and five private customers have been trained.

Each vehicle is maintained monthly, including inspection of brake fluid level, light function, and tire pressures. This inspection helps assure the vehicle's are in safe operating condition.

Conclusion: Our goal is a safe vehicle demonstration program. The main conclusion of the Safety Review was that thoroughly training vehicle operators in all parts of safe vehicle use was our best assurance of a safe program.

Attachments:
1. Safety Training Hand-out: " City-el Operation and Safety Training"
2. McClellan AFB safety documentation.

City-El OPERATION and SAFETY TRAINING Session

Purpose:

The purpose of this training session is to familiarize ALL vehicle operators with the safe operation of the City-el electric vehicle. The City-el is not a car. It is a special personal transportation vehicle designed to minimize the quantity of energy used to move people and a small amount of cargo around. Because of the three wheeled design, it has unique handling characteristics which are different from either a car or a motorcycle. Vehicle operators are responsible for use of the vehicle within it's performance limitations.

Project Overview:

We are utilizing the City-el for a research project funded under ARPA Grant MDA972-93-1-0025. Most people make many trips by themselves, which are less than 20 miles in length, and which require only modest speeds. This transportation category has been called the Neighborhood Electric Vehicle, or NEV. Because the City-el uses about 1/10 the quantity of energy of a conventional car or pick-up, it is in concept an ideal NEV to fill these personal transportation needs. The goal of our research project is to understand the amount of energy used as a function of the driving cycle, such that improved NEV's and NEV subsystems can be developed and manufactured locally. We are also interested in all operator comments regarding the features and attributes of the vehicle, since meeting customer's needs is the most effective way to enable local production. During the project we will be servicing the vehicles monthly, or more frequently, and downloading the Data Acquisition System (DAS).

Summary:

In this training course, the following information will be covered:

- Vehicle Handling Characteristics
- Ingress, Egress, and Operator Interface
- Vehicle Displays and Controls
- Driving The Vehicle
- Safety Interlocks
- Charging
- Basic Safety Review

After the class room portion, each operator will be provided with ***hands on instruction*** in the use of the vehicle, and in the basic maintenance operations.

Two Ground Rules:

1. There is no such thing as a dumb question. If you have an observation or a question, please ask.
2. Although this Training Course uses information from the City-el Instruction manual, it is not a substitute for reading the manual. Operators are responsible for reading and understanding the City-el Instruction manual.

Vehicle Handling Characteristics:

The City-el is a very light weight vehicle (640 lbs without driver or cargo). Three wheels were used in the design to minimize rolling resistance by eliminating front wheel scrub which occurs on four wheeled vehicles. This design choice makes the handling of the vehicle unique.

Because the vehicle is light weight, the driver and cargo make up a large part of the vehicle's operating weight and mass, the location and weight of the driver and the cargo have a significant influence on the handling characteristics of the vehicle. Please see figure 1.

As is seen from the figure, the center of gravity is higher in the vehicle when an operator sits in it. Most of the vehicle weight is on the rear wheels.

You can also see that the center of gravity is above the roll center of the front and rear suspension. For this reason, the vehicle tends to roll outward in turns. If turns are attempted at too high a speed, the vehicle will tip over. ***For this reason, always slow to a safe speed before making turns.*** When you first use the vehicle, brake only in a straight line. Always gently drive through turns.

The maximum design speed of the vehicle is 55 km/h, or 34 miles per hour. It is irresponsible to drive at a speed above the maximum design speed. Approach down-hill roads with care, and coast to save energy. It is best to use the brakes gently when the speedometer indicates a speed more than 34 miles per hour (mph), and this is why the speedometer is red in this region.

Ingress, Egress, and Operator Interface:

(Review Instruction Manual pages 6-9, attached)

Vehicle Displays and Controls:

(Review Instruction Manual pages 10-15, attached)

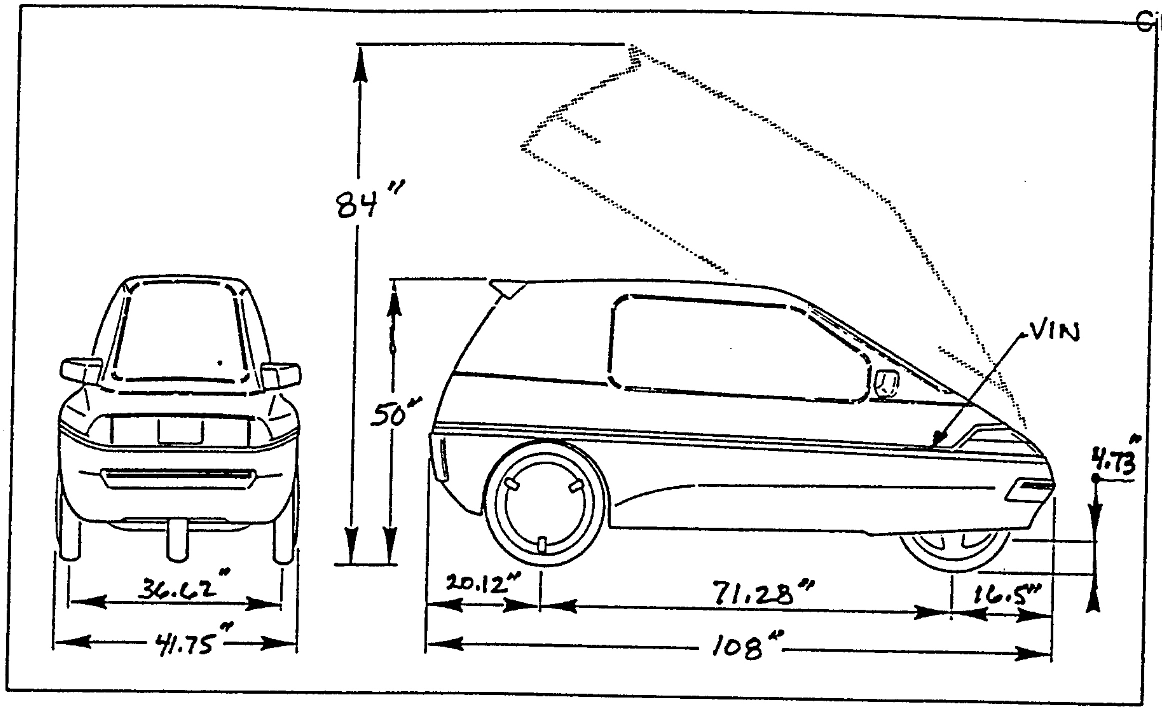
The location, interpretation, and operation of displays and controls are reviewed again during the hands on portion of the class.

Driving The Vehicle:

1. Before Operating Vehicle:
   - Visually verify tire inflation
   - Verify energy available is sufficient for the trip. This is done by turning on the ignition switch, and viewing capacity gage. The vehicle gives about 2 miles (3 km) per dot, more for experienced operators, less with heavy acceleration, many brake acceleration cycles, higher speeds or hills)
   - Verify Battery Cover is in place and bolted down.
2. Unplug the vehicle, first from the wall socket, then, if the charger is to be left in the garage, it may then be unplugged and stored.
3. Adjust the seat if necessary.
4. Sit in the vehicle and close the canopy.

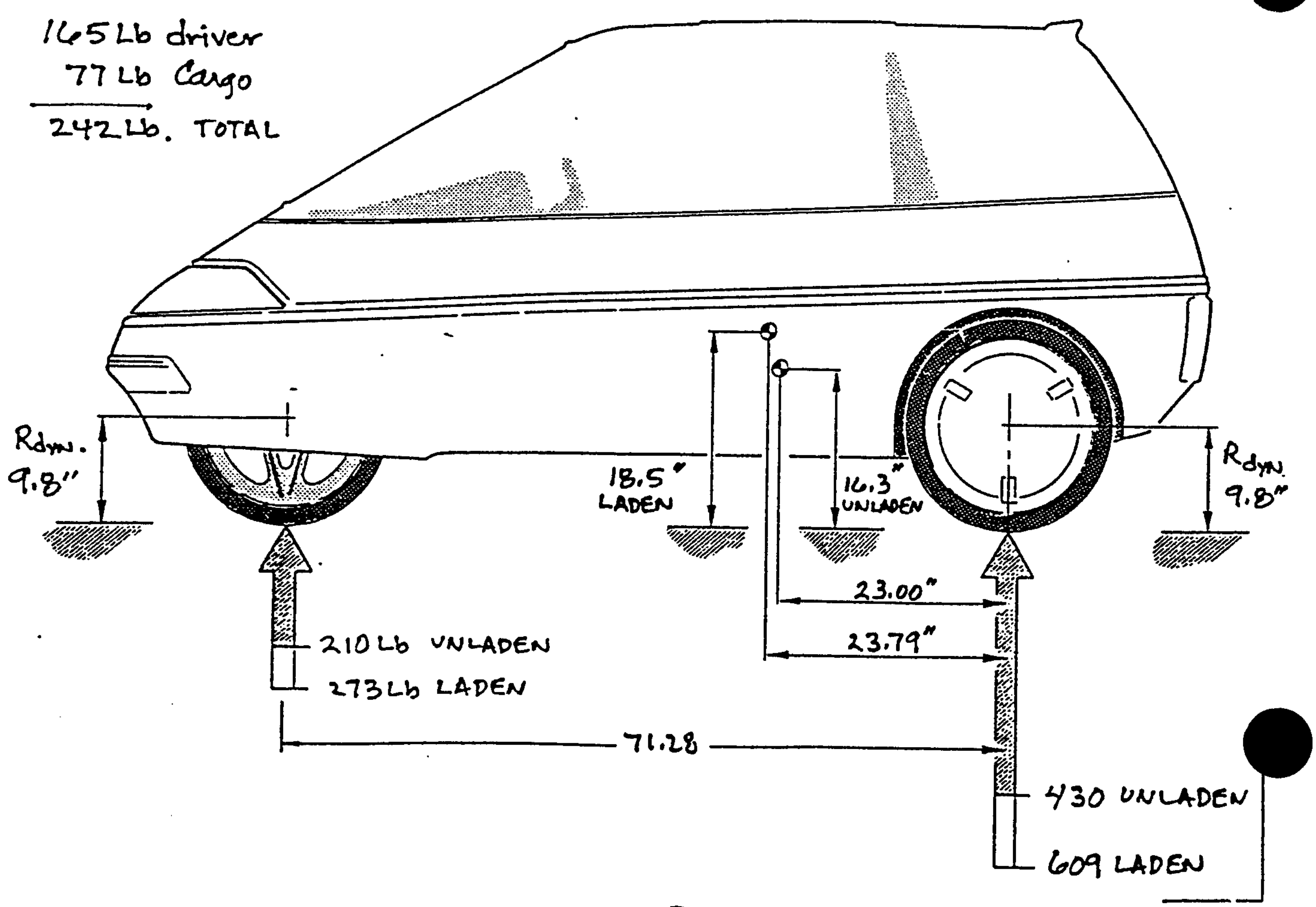
CityCom A/S

FIGURE 1



LOADED VEHICLE:

165 Lb driver
77 Lb Cargo
242 Lb. TOTAL



Driving the Vehicle, continued:

5. Fasten the Seat Belt.
6. Put on your helmet.
7. Turn on the Head lamp.
8. Mirrors are adjustable from inside the vehicle
9. Check that the horn works. (the vehicle is very quiet during driving, and you may need it to warn pedestrians or other vehicles.)
10. Release Parking Brake
11. Select forward or reverse using the driving forward-reverse lever. (only when vehicle is stationary.)
12. The clicking sounds heard when the accelerator is initially depressed are the electrical contactors or switches which allow current to flow to the motor.

Driving Tips:
Very low energy use can be achieved by looking as far ahead as possible while driving. Most energy is used during acceleration and at higher speeds. Accelerating gently using only part of the accelerator travel during acceleration will maximize range. Avoiding unnecessary braking by coasting as intersections or stops are approached also minimizes energy use and maximizes range.

Safety Warnings:

- When driving down hills it is irresponsible to exceed the maximum design speed of 34 miles per hour (55 km/h). Use the brakes to maintain a safe speed.
- Always adapt your speed on curves according to the driving conditions. Attempting to corner at too high a speed will cause the vehicle to roll.
- The City-el has low ground clearance, watch for speed bumps, pot holes, and other road surface irregularities.
- Avoid driving parallel to rail road tracks or similar road surface features, because of the narrow tires.
- Observe the maximum weight load limit of the vehicle, 240 lbs including driver. Never carry a passenger.
- Do not move the forward-reverse lever except when the vehicle is stationary.

Maximum Range: The maximum discharge of the batteries is controlled by the Capacity Gage. When the maximum range is reached, the vehicle will switch itself off. The battery indicator may give you an additional warning by coming on during acceleration. Do not attempt to travel further than the capacity gage indicates is possible, you may end up walking.

Parking the Vehicle

Whenever leaving the vehicle, always do the following:

1. Engage the parking brake.
2. Place forward reverse switch in neutral.
3. Switch off the lights.
4. Turn off vehicle and remove the key.

5. Connect the charger to charge the batteries, if possible. If the charge transformer has been removed from the vehicle, plug it into the vehicle before plugging in to the 110 V AC outlet.

Safety Interlocks:

The Vehicle is equipped with the following Safety Interlocks:

- Canopy Switch: This switch prevents driving with the canopy open.
- Charger Interlock: Prevents driving while the charger is plugged in.
- Low Voltage Cut-out: will switch vehicle off if driving with worn out or over discharged batteries is attempted. There is a warning lamp which lights up, providing a warning.
- Emergency Stop Switch, cuts power to control system and drive.
- Speed and Current Limit: There is a speed limiting control which is adjusted to limit the maximum speed on level roads to 34 mph (55 km/h).

Note: Charging will not occur with ignition key switch on, because of charger interlock.

Charging:

The sequential procedure is as follows:

1. Make sure the charge transformer plug is connected to the vehicle and the connector is latched.
2. Make sure the fan in the under seat compartment is clear and un-obstructed.
3. Turn off the ignition switch.
4. Plug in the charger to a 110 V ac outlet rated for at least 15 Amps.
5. Make sure charge light on dash is illuminated.

For maximum battery life, the vehicle should be plugged in when not in use for more than one (1) hour. The charger automatically controls the charge time according to the amount of energy used. If the capacity gage is on zero, it will take 8-10 hours to recharge the batteries fully. The gage shows 1/1 when the batteries are fully charged.

It may take 6-7 hours to reach a full charge even after only short trips. This is because the charger's memory remembers any interrupted charges and tries to compensate for them, before indicating full recharge. Because of this memory, it is advised that charging for less than one hour be avoided. Opportunity Charging, or plugging in whenever stopping, may be used when required to fill the operator's transportation mission.

Safety Warnings for Charging:

- Batteries produce Hydrogen gas during charging.

    Never smoke or allow open flame or sparks in proximity of the batteries.

    Always assure there is adequate ventilation in charging area. About 4.5 cubic feet of hydrogen gas is produced each charge cycle.

- Always use proper safety when plugging in the vehicle. Avoid standing in puddles or using wet plugs. Keep electrical connectors clean and dry. Plug charge transformer into vehicle before plugging into 110 V outlet. Improper plugging and unplugging can cause electrical shock.

• Batteries contain sulfuric acid. Keep battery acid away from eyes, skin, and clothing. Acid splashes should be washed off quickly with plenty of water. In case of eye contact, flush with plenty of water and continue flushing until medical attention is present.

• **Only qualified, trained personnel are allowed to service batteries for safety and data acquisition reasons.**

Basic Safety Review:

Never leave the keys in an un-attended vehicle.
Only qualified operators, who have had this class are allowed to drive the vehicle.
Read and understand the operators manual and the content of this class.
Wear a helmet and the seat belt while operating the City-el
Always use good judgment when operating this vehicle. Be aware of the vehicles characteristics.
Always observe the weight capacity limits of the vehicle, and never carry another person.
Head lights are to be turned on while the vehicle is in operation.
Always slow to a safe cornering speed.

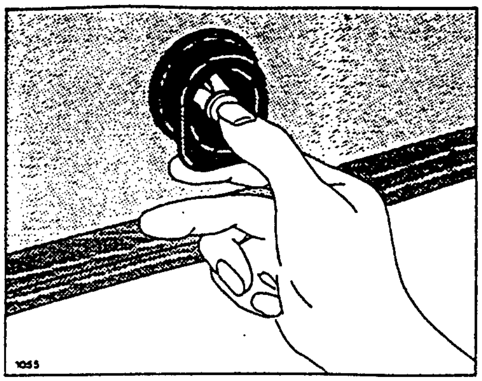
<u>Project Contacts:</u>
In the event you have trouble, or have a damaged or disabled vehicle, or have a question:
Please contact:
Bill Warf: Pacific Electric Vehicles at 381-3509, home 707-485-0652
George Broad or Sal Caravello at Drive Electric at 442-5110
On McClellan AFB contact :
RON COOMES 643-5443

<u>Hands On Instruction:</u> During hands on be sure you review and know how to do the following:
Review ingress and egress, opening and closing canopy.
Review how to adjust seat.
Review controls and displays location and function.
Explain how to check tire pressure.
Review cleaning and wiping down procedures.
Show location of charge transformer and charger, and explain charging procedure.
Show location of batteries, and how battery cover fits.
Show proper installation of battery hold downs.
Each and every operator in training must drive the vehicle.

Questions and Answers.

open – close – lock

6



Opening from the outside

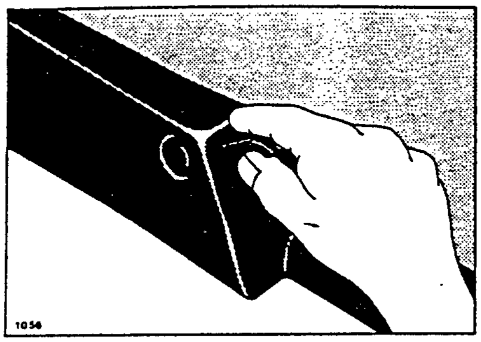
The canopy is opened by pressing the button in the handle and lifting upwards.

Closing from outside

Close the canopy completely and give the handle a light push downward, a small click indicates that the canopy is closed.

Locking

The canopy is locked by putting the small key into the lock in the button in the handle. When the vehicle is locked, the button cannot be depressed.



Closing from the inside

Grip the canopy frame with both hands and pull down to closed position; click shut by pushing down with both hands on the frame at either side.

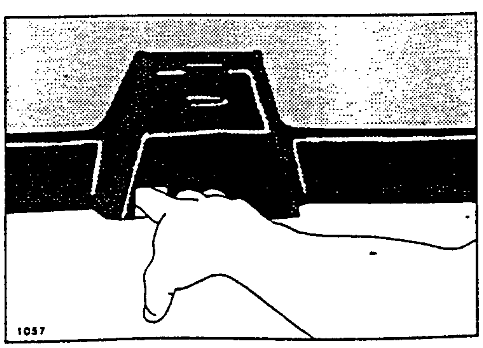
Opening from the inside

Release the handle on the right hand side and push forward and up on the steering wheel.

Please note: When the canopy is open the motor is disconnected and the vehicle is not drivable.

entry and luggage space

7



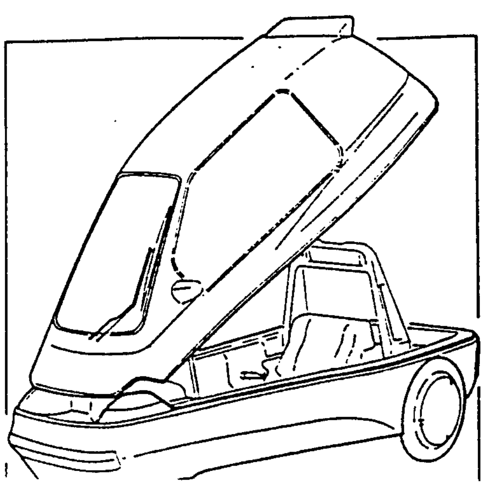
Emergency trigger in the lock

The lock in the canopy can be triggered in an emergency from the inside by pressing directly on the locking arm which is accessible through the cutout in the interior lock cover.

The vehicle is not lockable from the inside.

Entry

Having opened the canopy the driver can now enter the vehicle from either side.



Luggage space

Luggage is placed in the space behind the driver and on the lid of the motor compartment. The luggage space is designed for a maximum of *38 kg*.

Load and weight

Due to consideration of directional stability and braking distances, the combined weight of driver and luggage must not exceed:

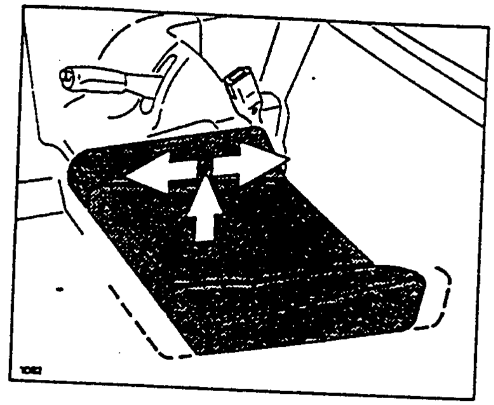
110 kg if the carger is carried.

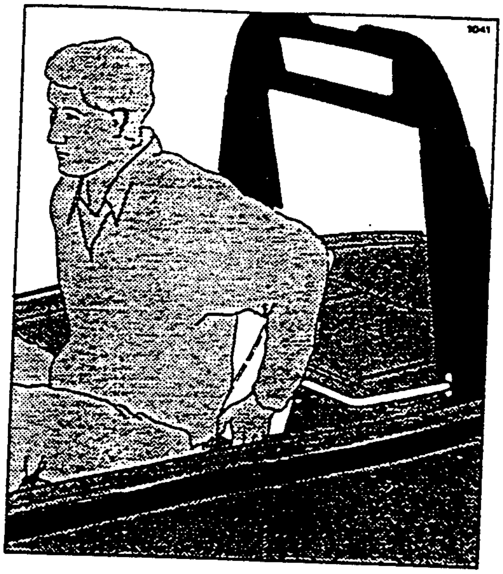
driving seat

A good driving position makes for better driving and less fatigue. Therefore make sure you adjust the seat and back-rest correctly in order to achieve maximum comfort.

Adjusting the seat

The seat is held in place with Velcro and so can be fixed in any position. Lift the seat up and place it so that it is easy for you to reach the pedals. When the seat is in the required position, press down firmly.





Adjusting the back-rest

The back-rest is adjustable forwards and backwards and is locked in place by a friction joint.

While seated in the vehicle, grip with both hands at the bottom of the back-rest as shown in the illustration.

Release the locking mechanism by lifting the back-rest upwards, pull forwards or push backwards for correct positioning.

Lock the back-rest into position by pushing downwards.

safety belt

The vehicle is equipped with a 3-point inertia belt.

Fastening of belt

When fastening the belt it should be reeled out gently to avoid the mechanism locking.

Holding the belt-buckle, pull the belt out diagonally across your chest.

Push the buckle into the lock and make sure the belt is not twisted.

Releasing the belt

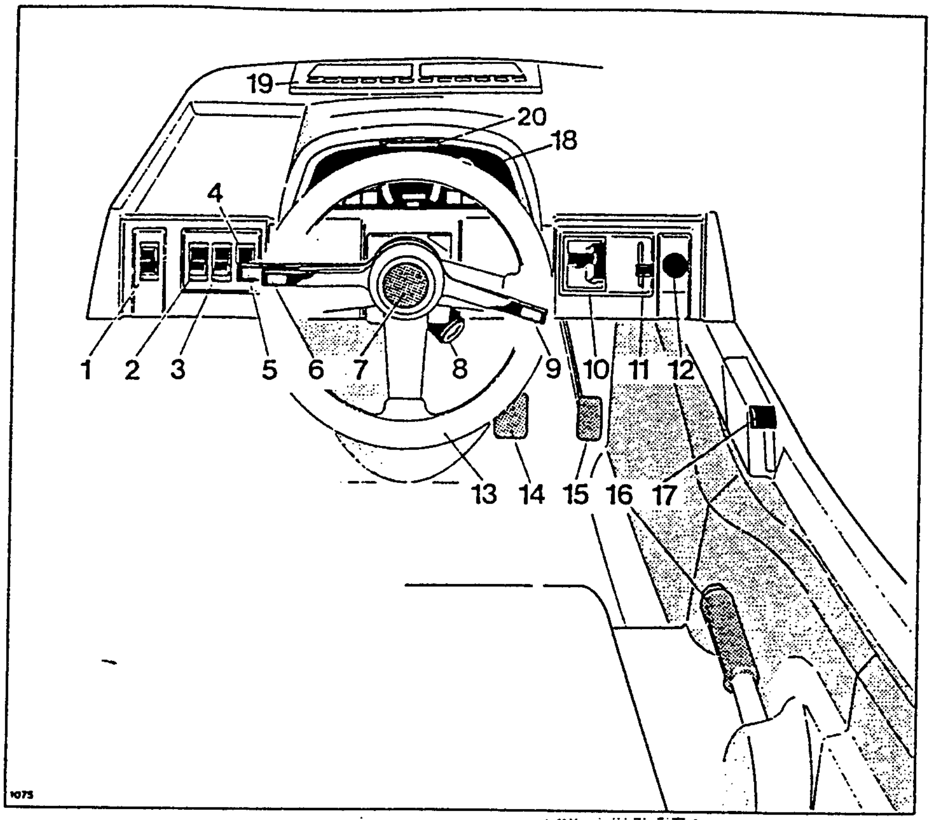
Hold the buckle and press the red release button on the lock.

Return the belt to the upmost anchor point.

Please note: The belt must be renewed if it has been subjected to excessive strain or has worn out.

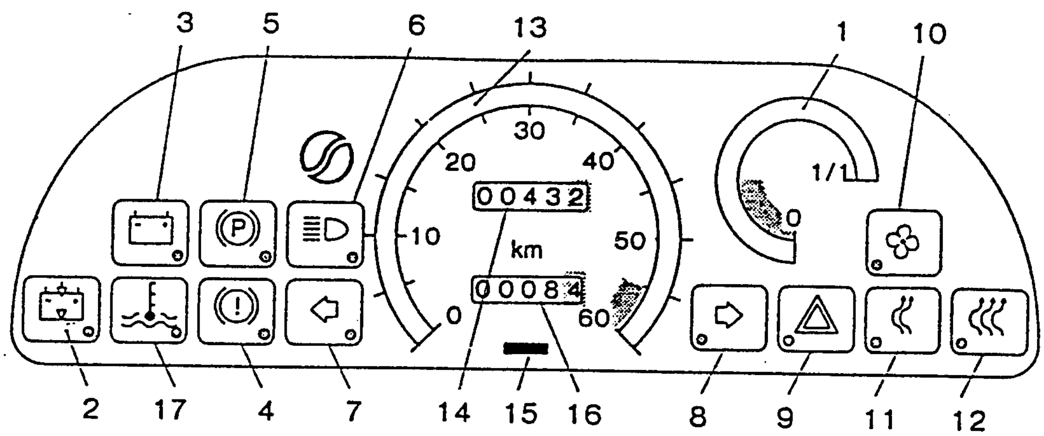
At the same time check the anchor points

switches and operating levers



1 Switch for hazard warning lights
2 Switch for ventilation fan
3 Switch for low and high heat
4 Switch for parking lights, full and dipped beam
5 Full and dipped beam stalk
6 Indicator stalk
7 Horn
8 Combined ignition and steering wheel lock
9 Screen wiper and washer stalk
10 Forward/reverse selector
11 Ventilation control
12 Emergency stop
13 Steering wheel
14 Brake pedal
15 Accelerator
16 Parking brake
17 Release lever for the canopy lock
18 Instruments, check and warning lamps
19 Ventilation grille
20 Cabin light

Instrument module



1 Battery gauge
2 Check lamp for connected charger
3 Battery lamp (LOW BAT VOLT.)

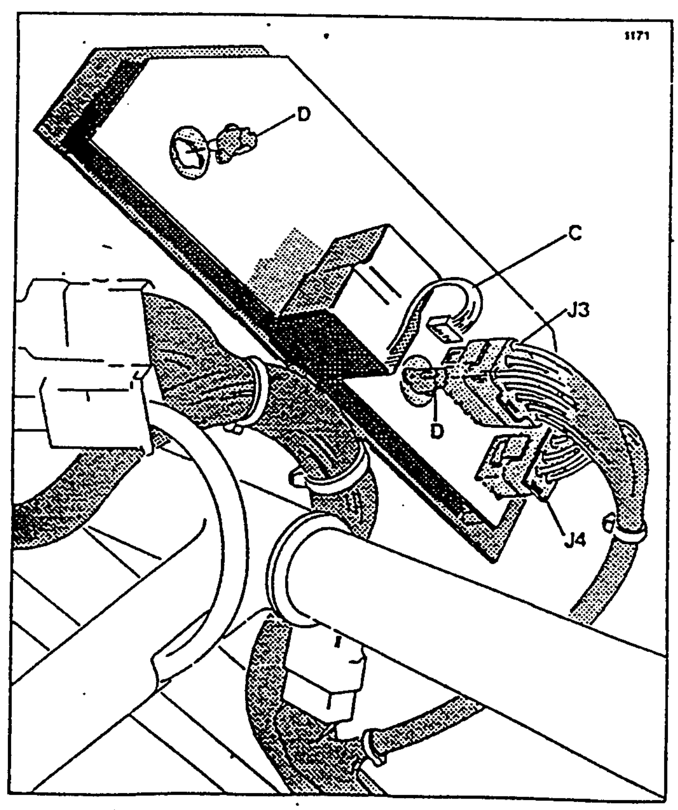
4 Warning lamp for low brake fluid level
5 Check lamp for parking brake on
6 Check lamp for full beam on

7 Check lamp for indicator left
8 Check lamp for indicator right
9 Check lamp for hazard warning lights

10 Check lamp for ventilation fan
11 Check lamp for low heat
12 Check lamp for high heat

13 Speedometer
14 Kilometer-counter
15 Zero button for trip-recorder
16 Trip-recorder

17 Not used



Battery check lamps

Charger

The check lamp comes on when the vehicle is connected to the charger.

The vehicle can not be driven when the charger is connected.

Battery lamp

The check lamp lights up intermittently during overworking of the battery. The reason can be driving up long gradients, insufficient charging or possible faults in the battery.
The function of the lamp is described in detail in the section on battery discharging. See page 28.

Check lamps for lights

Full beam

Lights up when full beam is on.

See page 17.

Indicators

Flashes when indicators are used.

See page 16.

Hazard warning

Flashes when hazard warning is switched on.

See page 16.

Warning and check lamps for braking system

Parking brake

The check lamp is on when the parking brake is applied.

See page 22.

Brake fluid

The warning lamp lights up if the level of brake fluid has become too low. Do not drive the vehicle!!!

When filling up the brake fluid container, *use only the prescribed silicone brake fluid.* See page 37.

Check lamps for the ventilation and heating system

Ventilation fan

The check lamp is lit when the fan is switched on.

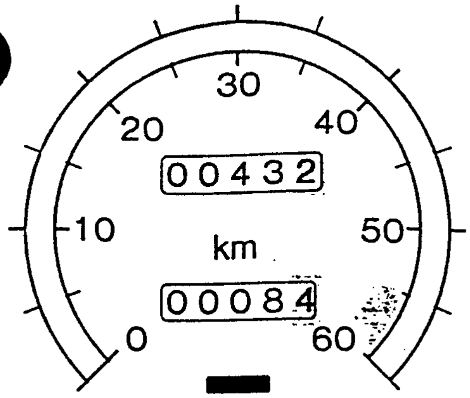
See page 18.

Heating

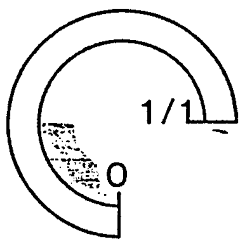
The check lamp is lit when either the small or the large heating element is activated.

See page 19.

Speedometer



Battery gauge



The speedometer shows the speed of the vehicle in kilometers per hour. The speed must not exceed 55 km/h as indicated by the red section.

The upper counter in the speedometer shows the total number of kilometers the vehicle has covered. The last digit changes every 100 meters. The illustration shows that the vehicle has covered 43,2 km.

The lower counter in the speedometer is a trip-recorder which is zeroed by pressing the button under the counter. The trip-recorder changes every 100 m. The illustration shows that 8,4 km have been covered since the trip-recorder was zeroed.

The battery gauge indicates how much energy is left in the batteries. When the batteries are fully charged the indicator will be on 1/1. The vehicle can be used at any point between 1/1 and 0.

During use, the energy indicator will drop, at a rate depending on driving conditions at the time. Driving in a town with frequent starts and stops uses more energy than driving on a level country road. Therefore you will not be able to drive as many kilometers in a town as on a country road.

When the stored energy has been used up the indicator will be on 0, the vehicle will stop and the batteries will have to be recharged before the vehicle can be driven again.

technical data

Construction

Body Sandwich construction consisting of external and internal glass fibre reinforced thermoplastic moulded acrylic/ABS shells. The cavity is filled with rigid polyurethane foam (non freon).

Canopy Thermoplastic moulded acrylic shell, bonded to a frame of steel reinforced rigid polyurethane foam.

Screens Front screen laminated glass. Side windows toughened glass. (Side windows only in certain countries).

Weight

Weight including batteries and charger	290 kg
Maximum load (including charger)	110 kg
Maximum load (excluding charger)	120 kg
Maximum total weight	400 kg

Charger

Built in electronic charger with automatic programming and control of charge. External mains unit connected to the vehicle via special socket.
The charger can be carried in the vehicle.

Mains supply	110/220 V/AC + 15/-10%, 60/50 Hz

Warning:

Mains supply according to the label on the charger box.

Batteries

Specially produced for the vehicle. Modified lead/acid heavy duty battery, three per vehicle.

Type	Rocket
Voltage per battery	12 V
Dimensions	356 x 268 x 238 mm
Weight per battery	31 kg

Please note: Use only this type of battery for compatibility with the electronic components.

Braking system

Service brake:	Hydraulic dual circuit system. Drum brakes in all wheels.
Parking brake:	Mechanical hand brake operating on both rear wheels.
Drum diameter:	136 mm.

Brake fluid

Silicone based brake fluid according to specification SBF 1001 . DOT 5.

Please note: Use only this type.

Performance

Speed, level road	40 km/h
(with special equipment	50 km/h)
Range per charge at temperatures of over 10°C	30-50 km
(depending on driving conditions)	
Frontal area	0,99 sq.m.
Aerodynamic dragcoefficient Cd	0,32

Motor

36 V DC compound wound motor with fan cooling.

Norminal power at 2500 rpm	2,5 kW
Maximum effect	3,6 kW

Motor controller

Motor controller in heat sink housing.

Maximum current to motor	215 A +/- 5 A
Frequency	15 kHz

Transmission

Traction from motor via polyvee belt to rear axle. Self adjusting belt tensioner. Rigid rear axle with friction clutch on right rear wheel.

Suspension

Rear Quarter elliptic, longitudinal leaf springs. Double acting, hydraulic, telescopic dampers.

Front Leading link suspension, coil spring and telescopic damper.

Steering

Toothed sector with bevel pinion; telescopic steering column.

Gear ratio	8 : 1

Wheels

Cast aluminium with integral steel brake drum.

Rim dimension	1,85" x 16"

Tyres

Type	80/70 x 16"

Please note: Use only this type.

Pressure front	35 PSI = 2,4 kg/sq. cm
Pressure rear	37 PSI = 2,5 kg/sq. cm

All the above statements are good reasons for driving an electric vehicle. But, why a City-el? The following discussion explains why it is so important for an electric vehicle to be as small as the City-el:

The reason for the low range of an electric vehicle compared to a gasoline powered vehicle is because of the energy density stored on board:

- the energy stored in gasoline is 12,000 wh/kg
- the amount stored in a lead acid battery is 32 wh/kg

Most of the energy required in a car is for getting the 3 - 4,000 pound mass moving down the road. The development of today's gas cars has been based on the high energy density of the gasoline carried on board. They could afford to weigh alot and have seating for four to six people when 93% of the time the driver is alone in the car.

The development of successful EVs has also been based on the energy density of the batteries carried on board. In the City-el, the energy requirements have been reduced by dramatically reducing the weight and size of the vehicle. Since most of the time, only one person is in the car, it is built for one. The reason for three tires instead of four is to further reduce the rolling resistance and energy use. This results in the most efficient production EV on the road today.

The cost of battery replacement is another issue in a successful EV. Batteries available today are not designed for the energy and power demands of a large heavy EV. The reduced size and weight of a City-el makes it the only practical EV for battery life of over two years and low cost battery replacement.

STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname), GRADE AND DATE		TO	ACTION	SIGNATURE (Surname), GRADE AND DATE
1	SM-ALC/SE	Coord	James Sablotny LtCol	6			
2	652 ABG/SP	Coord	Mueller Meyer (Secomd) 17/11/93	7			
3	652 ABG/CE	Coord	Haggithorn LtCol 15 Nov 93	8			
4	652 ABG/CD	Coord	McNulty, LtCol, 17 Nov 93.	9			
5	652 ABG/CC	Coord	Russo Col 18 Nov 93	10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INITIALS	SUSPENSE/DATE
Senuta/SSgt	EM	3-3672 ext169		

SUBJECT	DATE
Neighborhood Electric Vehicle (NEV) Project	8 NOV

SUMMARY

1. In response to the Base Traffic Safety Coordinating Group (TSCG) 2~~0~~5 Oct 93 meeting (tab 1), the following test plan is submitted for your coordination.

2. Congress directed SM-ALC to establish an electric vehicle (EV) research, development and demonstration program. Our program is demonstrating EV technologies in several applications. One project is to demonstrate light weight, ultra-efficient NEVs. The mini-el vehicle was chosen for our 1 year demonstration at McClellan AFB.

a. Vehicle Type. The mini-el is a three wheeled, light weight, single passenger vehicle (see tab 2 for specifications).

b. Operator Training and Licensing. We have established a training and licensing program with the 652 ABG/LGHVO, Vehicle Operations Unit (tab 3). drivers will be fully trained and licensed.

c. Safety. The mini-el meets all applicable CFR 599 safety standards including 49 CFR 571.122 brake tests (includes dry and wet braking). Helmets will be supplied and worn to comply with California law. To increase visibility, safety flags will be installed on all vehicles and the headlight will remain on when the vehicle is in motion.

d. Maintenance. Leasing agency personnel will perform vehicle maintenance.

e. Charging Stations. Each vehicle has an on-board battery charger that uses a standard 120V household outlet. The outlets being used on McClellan AFB are GFI safety outlets. When the batteries are fully charged, the charger automatically shuts down. We are working additional charging station locations and designated parking with CE and the Traffic Engineer.

f. Data Acquisition. An automated data acquisition system will be installed on each vehicle. We will use the information to establish the day to day driving habits of the various users and the vehicles' energy consumption. We and the Advanced Research Projects Agency (ARPA) will use the data to help in the development of future EV specifications.

g. BOS MEB. The EV Program Manager, Mr Philip Mook, will brief the NEV program at the next available BOS MEB meeting.

RECOMMENDATION.

3. Coordinate on the 1 year NEV test program.

THO[illegible], GS-[illegible]
Associate Director,
Environmental Management

3 Tabs
1. TSCG Minutes
2. mini-el Fact Sheet
3. mini-el Lesson Plan

DEPARTMENT OF THE AIR FORCE

HEADQUARTERS SACRAMENTO AIR LOGISTICS CENTER (AFMC)
McCLELLAN AIR FORCE BASE, CALIFORNIA

FROM: SE   26 Oct 93

SUBJ: Meeting Minutes of the Base Traffic Safety Coordinating Gp (TSCG)

TO: 652 ABG/CD   652 ABG/CE   652 ABG/SP

1. The TSCG convened on 25 Oct 93 at 0900 to discuss traffic safety issues. Items discussed included stop signs, lighting near building 243, and the use of the City-el electric vehicle.

2. Members present:

Lt Col James P. McNulty, 652 ABG/CD, Chairman, 3-0652
Mr Richard Hight, Safety Office, Recorder, 3-5537
MSgt James Larson, Security Police, 3-5522
Mr Dick Donnelly, Civil Engineering, 3-3336

3. A TI request to install stop signs on the west side of Building 243 was approved since this area in under the control of TI. A work order should be submitted by the building manager.

4. The Civil Engineering Traffic Engineer was tasked to review the intersection of Dudley Blvd and Dudley Loop to ensure morning inbound traffic does not conflict when making a left turn onto Dudley Blvd.

5. Civil Engineering was tasked to review and make comments regarding improvements to lighting at Peacekeeper Way and Bailey Loop and along the west side of Building 243 through Building 244.

6. Discussion regarding the City-el electric vehicle concluded that there may be an increased risk to the operator due to the lack of front, side, and rear impact protection, the inherent instability of a 3 wheel vehicle, and its low profile (small size). Since these vehicles have already been leased, the TSCG concurs in the continued test subject to the following conditions:

a. Bicycle type flags will be installed on each vehicle to increase visibility.

b. A coordinated test plan/safety analysis will be accomplished and EM will brief the BOS MEB on the planned use/safety issues identified.

c. A driver training plan will be coordinated prior to the start of training and only those operators trained will be licensed to use this vehicle.

d. Use of this vehicle will be limited during periods of inclement weather.

16.4

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SACRAMENTO AIR LOGISTICS CENTER (AFMC)
McCLELLAN AIR FORCE BASE, CALIFORNIA

FROM: SM-ALC/JA

22 Oct 93

SUBJ: Helmet Requirements for the Operations of SMUD 3-Wheeled Vehicles

TO: 652 ABG/CC

1. I have researched the applicable regulations and laws regarding the wear of helmets while operating the SMUD 3-wheeled vehicles, and have discovered that helmets must be worn while operating the 3-wheelers here at McClellan AFB.

2. Air Force installations do not have their own traffic laws because there is no federal vehicle code establishing traffic laws on federal property. Therefore, according to AFR 125-14 and Department of Defense Directive 5525.4, Air Force installations must adopt the traffic laws of the host state. However, there are certain exceptions to this general rule concerning such issues as motor vehicle licensing requirements and driver's licensing requirements. I have found no exception that would exempt Air Force employees from complying with the California motorcycle helmet requirements, either off-base or on-base.

3. The California Vehicle Code classifies 3-wheeled vehicles as motorcycles for the purposes of the helmet requirement, but not for the purposes of any licensing requirements. Therefore, a 3-wheeled vehicle can be considered a car for licensing requirements, but is a motorcycle for helmet requirements.

4. Safety and liability considerations support the above determination. The 3-wheeled vehicles are not nearly as crash-safe as standard 4-wheeled vehicles, which is a major reason for the motorcycle helmet requirement. Therefore, if an Air Force employee was injured while operating one of the 3-wheelers, the government would be exposed to liability for not supplying the necessary helmets.

5. If you have any questions, please call Capt Banna at 3-6700.

AARON S. SPRINGER, Maj, USAF
Acting Staff Judge Advocate

1 Atch
Action Line Response
cc: SM-ALC/EMP
652 SPS/SPOI

Test Report, Wear Evaluation on the City-el Electric Vehicle

1 April, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance L. Atkins & William R. Warf
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

City-el Wear Evaluation Plan.

This document outlines a wear evaluation plan for the City-el vehicles being utilized in the Neighborhood Electric Vehicle (NEV) Project. The intent of this plan is to provide a means to evaluate City-el components for use in a locally manufactured and assembled neighborhood electric vehicle. This test plan is requested in Attachment B as part of Participation Agreement F-102 between SMUD and Pacific Electric Vehicles. The project is funded in part by ARPA grant MDA972-93-1-0025, however the content of this report should not be construed to reflect the views of the government. .

Overview

Vehicle components are to be measured on a biannual basis on up to six vehicles. A data sheet form for recording the wear measurement data is included at the back of this report along with a completed sample data sheet. A quick list of the components to be measured and their specified tolerances are listed below. Additional Components may be evaluated as they wear or patterns of service problems occur. These will be added to this plan by revision.

The following list of components are to be measured:

- Motor brush length (All 4 brushes)
- Commutator diameter
- Pulley runout, (Drive Pulley)
- Brake shoe thickness
- Brake drum internal diameter

These components have the following manufacturer specified tolerances:

- Min. motor brush length = 11mm
- Max. pulley runout = +/- 1.0mm
- Max. brake drum diameter as measured with a 3 point gage = 137mm
- New brake drum diameter as measured with a 3 point gage = 135.3mm (nom.)

The previous component tolerances in inches are as follows:

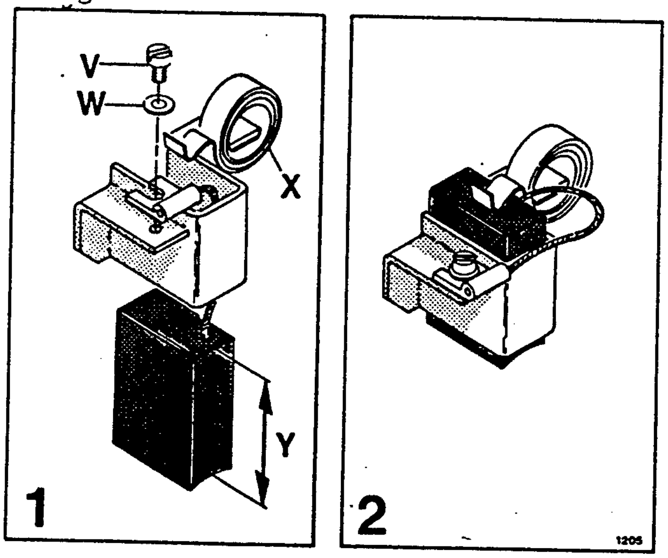
- Min. motor brush length = 0.433 in
- Max. pulley runout = +/- 0.039 in
- Max. brake drum diameter as measured with a 3 point gage = 5.398in
- New brake drum diameter as measured with a 3 point gage = 5.331in (nom.)

Wear Measurements

The location of wear measurements for each of the tested components is described in the paragraphs below. Each paragraph has a reference number which is shown on the data sheet. These reference numbers facilitate finding the information needed to take a wear measurement while working with the data sheet. Refer to the City-el workshop manual when ever necessary to find the correct disassembly and assembly procedures for the component.

W1. Motor brush length will be measured from the top of the arch where the brush meets the commutator to the top edge of the brush. Refer to figure 1a. It is not necessary to remove the brushes in order to make the measurement. The brush number can be determined in the following manner. On the outside of the motor end plate, one of the terminals is marked with an A1. This terminal is adjacent to brush 1. The other terminal is marked with an A2, and this terminal is adjacent to brush 2. Continue numbering the other two brushes in a clockwise direction while looking at the outside of the motor end plate. Refer to figure 1b.

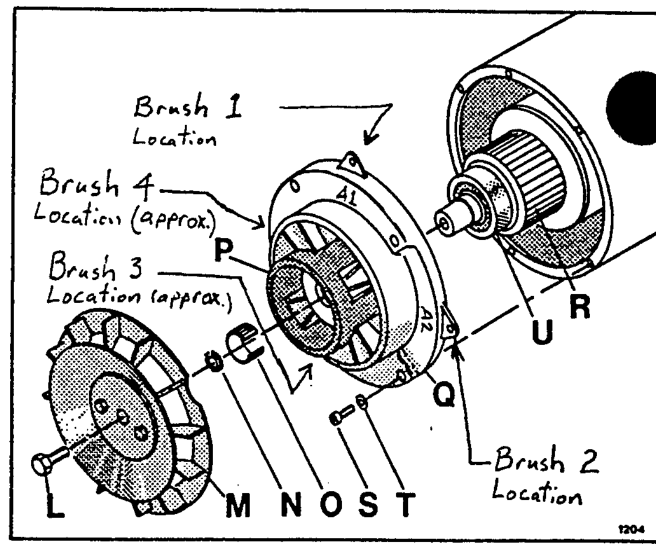
Figure 1a



Brush

V: screw, W: washer, X: spring, Y: length of brush

Figure 1b



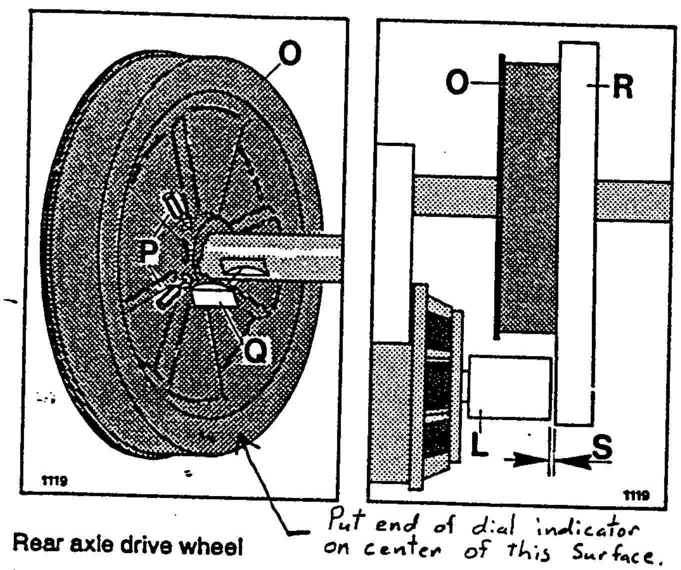
Motor end cover

L: bolt, M: fan blade, N: washer, O: spring bush, P: brush holder, Q: end cover, R: commutator, S: screw, T: washer, U: bearing

W2. Commutator diameter will be measured as close as possible to the middle of the zone where the brush meets the commutator. Get as close as possible without removing the armature from the motor.

W3. Pulley runout will be measured using a dial indicator attached to the battery box. The end of the dial indicator will be placed against the flat surface of the pulley just below the belt. Refer to figure 2. Find and record the maximum and minimum measurements while the belt is on and while the belt is off. The actual amount of runout will be calculated from the maximum and minimum measurements with the following equation. Runout = maximum - minimum.

Figure 2

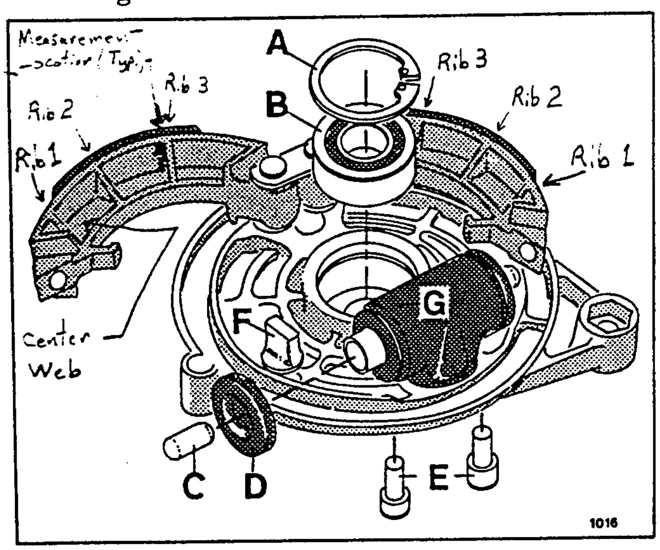


Rear axle drive wheel

L: motor drive wheel, O: rear axle drive wheel, P: screw, Q: Woodruff key, R: straight-edge, S: distance from straight-edge (R) to end surface of motor drive wheel (L)

W4. Brake shoe measurements will be made at the outside two ribs for each shoe on the rear wheels. These ribs will be referred to as ribs 1 and 3. Ribs 1 and 3 can be identified by counting sequentially starting with 1 from the rib closest to the brake cylinder. Refer to figure 3. For the brake shoes on the front wheel, measurements will be taken at ribs 2 and 3. The rib numbering system is the same as for the rear brake shoes. Brake shoe thickness will be measured from the surface of the pad material to the available surface of the shoe. Do not measure to the seam between the pad and the shoe. Measurements should be made on the outside edge of the shoe; not on the side that is against the backing plate. In simple terms, don't remove the brake shoe. The measurements should also be made on the side of the rib closest to the wheel cylinder. Finally, when doing any of the measurements place the end of the calipers against the center web of the shoe and make sure that the face of the caliper is flat against the brake pad. Try not to include the fillet that runs from the center web to the back surface of the shoe, and don't forget to place the calipers against the rib.

Figure 3



Back plate with brake cylinder

A and B: circlip and bearing. C and D: pin and collar. E: brake cylinder Allen screw. F: brake shoe stop. G: brake cylinder

W5. Brake drum interior diameter will be measured at approximately the center of the wearing surface. When making this measurement with calipers take extra care to make sure that the calipers are measuring the true diameter.

Wear Evaluation Plan Data Sheet

Date: 2/14/94

Data Taken By: Atkins

Vehicle Information.

VIN#: 4138

Odometer: 6.0

Motor Components. (b1, b2, etc. are brush numbers.)

Brush Length - W1: (in) b1 0.798 | b2 0.800

(All 4 brushes) (in) b3 0.798 | b4 0.798

Commutator Diameter - W2: (in) 2.485

Pulley runout with belt on - W3: (in) max 0.053 | min 0.029

(in) runout = max - min 0.024

Pulley runout with belt off - W3: (in) max 0.054 | min 0.032

(in) runout = max - min 0.022

Front brakes. (r2, r3 are brake shoe rib numbers)

Drum diameter - W5: (in) 5.354

Top Brake Shoe - W4: (in) r2 0.328 | r3 0.331

Bottom Brake Shoe - W4: (in) r2 0.353 | r3 0.328

Left Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5: (in) 5.351

Front Brake Shoe - W4: (in) r1 0.350 | r3 0.327

Rear Brake Shoe - W4: (in) r1 0.335 | r3 0.313

Right Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5: (in) 5.354

Front Brake Shoe - W4: (in) r1 0.360 | r3 0.330

Rear Brake Shoe - W4: (in) r1 0.337 | r3 0.320

NOTE: The "W" numbers listed by each measurement refer to a paragraph in the Wear Measurement section of the Component Test Plan. This paragraph describes the location of the measurement for that component.

Wear Evaluation Plan Data Sheet

Date: 3/4/94

Data Taken By: ATKINS

Vehicle Information.

VIN#: 4127

Odometer: 5.6

Motor Components. (b1, b2, etc. are brush numbers.)

Brush Length - W1: (in) b1 0.799 | b2 0.801

(All 4 brushes) (in) b3 0.800 | b4 0.799

Commutator Diameter - W2: (in) 2.487

Pulley runout with belt on - W3: (in) max 0.076 | min 0.053

(in) runout = max - min 0.023

Pulley runout with belt off - W3: (in) max 0.039 | min 0.016

(in) runout = max - min 0.023

Front brakes. (r2, r3 are brake shoe rib numbers)

Drum diameter - W5: (in) 5.354

Top Brake Shoe - W4: (in) r2 0.349 | r3 0.343

Bottom Brake Shoe - W4: (in) r2 0.341 | r3 0.320

Left Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5: (in) 5.354

Front Brake Shoe - W4: (in) r1 0.328 | r3 0.306

Rear Brake Shoe - W4: (in) r1 0.336 | r3 0.311

Right Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5: (in) 5.351

Front Brake Shoe - W4: (in) r1 0.337 | r3 0.315

Rear Brake Shoe - W4: (in) r1 0.332 | r3 0.320

NOTE: The "W" numbers listed by each measurement refer to a paragraph in the Wear Measurement section of the Component Test Plan. This paragraph describes the location of the measurement for that component.

Wear Evaluation Plan Data Sheet

Date: _______________

Data Taken By: _________________

Vehicle Information.

VIN#:	______________________________
Odometer:	______________________________

Motor Components. (b1, b2, etc. are brush numbers.)

Brush Length - W1:	(in) b1__________ | b2__________
(All 4 brushes)	(in) b3__________ | b4__________
Commutator Diameter - W2:	(in) ______________________________
Pulley runout with belt on - W3:	(in) max__________ | min__________
	(in) runout = max - min ___________
Pulley runout with belt off - W3:	(in) max__________ | min__________
	(in) runout = max - min ___________

Front brakes. (r2, r3 are brake shoe rib numbers)

Drum diameter - W5:	(in) ______________________________
Top Brake Shoe - W4:	(in) r2____________ | r3___________
Bottom Brake Shoe - W4:	(in) r2____________ | r3___________

Left Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5:	(in) ______________________________
Front Brake Shoe - W4:	(in) r1____________ | r3___________
Rear Brake Shoe - W4:	(in) r1____________ | r3___________

Right Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5:	(in) ______________________________
Front Brake Shoe - W4:	(in) r1____________ | r3___________
Rear Brake Shoe - W4:	(in) r1____________ | r3___________

NOTE: The "W" numbers listed by each measurement refer to a paragraph in the Wear Measurement section of the Component Test Plan. This paragraph describes the location of the measurement for that component.

Wear Evaluation Plan Data Sheet

Date: ______________

Data Taken By: ________________

Vehicle Information.

VIN#:	____________________
Odometer:	____________________

Motor Components. (b1, b2, etc. are brush numbers.)

Brush Length - W1:	(in) b1__________	b2__________
(All 4 brushes)	(in) b3__________	b4__________
Commutator Diameter - W2:	(in) ____________________	
Pulley runout with belt on - W3:	(in) max__________	min__________
	(in) runout = max - min	__________
Pulley runout with belt off - W3:	(in) max__________	min__________
	(in) runout = max - min	__________

Front brakes. (r2, r3 are brake shoe rib numbers)

Drum diameter - W5:	(in) ____________________	
Top Brake Shoe - W4:	(in) r2__________	r3__________
Bottom Brake Shoe - W4:	(in) r2__________	r3__________

Left Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5:	(in) ____________________	
Front Brake Shoe - W4:	(in) r1__________	r3__________
Rear Brake Shoe - W4:	(in) r1__________	r3__________

Right Rear Brakes. (r1, r3 are brake shoe rib numbers)

Drum Diameter - W5:	(in) ____________________	
Front Brake Shoe - W4:	(in) r1__________	r3__________
Rear Brake Shoe - W4:	(in) r1__________	r3__________

NOTE: The "W" numbers listed by each measurement refer to a paragraph in the Wear Measurement section of the Component Test Plan. This paragraph describes the location of the measurement for that component.

Rolling Resistance and Coefficient of Drag Testing on the City-el Electric Vehicle

12 April, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: William R. Warf
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

TEST REPORT:
Rolling Resistance and Coefficient of Drag Testing

Prepared by: William R. Warf, Pacific Electric Vehicles, 12 April, 1994

Purpose: The purpose of the Rolling Resistance Test was to arrive at an estimate of the rolling resistance coefficient and the aerodynamic drag coefficient for the City-el. These will be used in interpreting data acquired using the data acquisition system (DAS). These estimates may also be used to bench mark City-el performance, for use in other calculations. Our goal is to segment the losses in the City-el vehicle system such that we are able to achieve improvements compared with the City-el in the new Neighborhood Electric Vehicle which is entering a prototype phase.

Conclusion: The test method used and the measurements made resulted in a wide variation in test results. Averaging the test results suggests a drag coefficient (Cd) of about .45-.47, and a rolling resistance coefficient of about 0.014. This translates to a flat ground, no wind power requirement of about 1.8 kW at the wheel. This agrees well with the current normally drawn (about 60 Amps) on a rough asphalt road with an 85 kg driver. With the vehicle jacked up on blocks, spinning the drive line requires about 10 W/ mph measured at the battery. At 35 mph rotating the drive line requires about 350 Watts.

Because of the variations in the test results, the above coefficient of drag and rolling resistance measurements should be considered gross approximations. The test needs to be repeated with fewer assumptions and better equipment. Please see the Discussion of Results section of this report for details.

Test Method; Roll Down Test: The Roll Down test was conducted on December 15, 1993. Two vehicles were utilized, one SMUD owned driven by Jose Baer, with approximately 4500 km on the odometer (Jose's vehicle), and with a new vehicle recently acquired for the NEV project driven by the author (Bill's vehicle). Tire pressures were set before the test at 34 psi front, and 38 psi rear.

The vehicles were driven both directions on a fairly flat road and the time to coast from 50 km/h to 40 km/h and 30 km/h to 20 km/h with the power off was recorded for both directions. Speed in Bill's vehicle was measured using a Fluke 87 connected to the Tach signal in the City-el diagnosis box. We measured the wheel circumference and calculated the "counts" which corresponded with the speeds above. Times in Jose's vehicle were recorded using the speedometer in the vehicle. Time was recorded with a stopwatch. The times for each direction were

averaged in hopes of taking into account any slight slope in the road and wind resistance. The three best sets of data were averaged for each vehicle to perform the analysis in this report.

The analysis method is from the Bosch Automotive Handbook, 2nd edition, page 257. This method assumes constant deceleration. The vehicles were not weighed, so the mass of Jose's vehicle was assumed as 362 kg, and 376 kg for Bill's vehicle. The density of the air was taken as 1.202 kg/m^3. A sample calculation is attached to illustrate the method.

The road used was less than ideal, being not quite long enough. Marks on the road for consistent start stop points would have been helpful.

Test Method; Drive Line Power Test:
This test was performed at the suggestion of Jose' Baer, who has performed a similar test on the Horlacher. The method is to jack up the vehicle on blocks and to record the power withdrawn from the battery versus speed. Power is calculated from battery voltage and motor current for a speed indicated on the speedometer. Current is measured at the main shunt connection in the City-el diagnosis box with a Fluke 21. A Sensitive Research Voltmeter was used for battery voltage. Tests were performed on two vehicles to provide a comparison between vehicles.

Test Results:

Test results for the Roll Down test are provided in the tables ROLLDOWN.XLS (Bill's Vehicle), and ROLLDOW2.XLS (Jose's vehicle).

Test Results for the Drive Line Power Test are provided in FREEROLL.XLS, 2 pages.

Discussion:
As can be seen from the above tables, our measurements of time for the Roll Down test were not very consistent. To illustrate the variation, power versus speed for the average values from Jose's vehicle and Bill's vehicle are plotted in figure CELPOWER.XLS CHART 6. In this chart I have estimated the effect of mass variation on the power required, using a rolling resistance coefficient of 0.0135 and a Cd of 0.475. It can be seen from the figure that Jose and Bill values vary from the average by 11-13%, or +/- 208 Watts from an average of 1872 W at 35 mph. It can also be seen that the theoretical effect of very light drivers (50 kg) versus heavier drivers (82 kg) is about 100 Watts at 35 miles per hour.

In interpreting DAS data, we usually won't know vehicle mass, road surface slope, type of road surface, Canopy up or down, actual tire pressure, wind velocity, or actual air density. As seen from the Drive Line Power Test, variation in drive line power can be about +/- 50 W from vehicle to vehicle at 35 mph. This is assumed to be due to fits and wear in on the vehicles.

The following charts give an idea of the magnitude of power at the road needed to drive a City-el down the road.

CELPOWER.XLS Chart 1 shows the drive power versus speed for Bill's vehicle at the values measured.

CELPOWER.XLS Chart 2 shows the drive power versus speed for Jose's vehicle at the values measured.

FREEROLL.XLS Chart 2 shows the power withdrawn from the batteries in the Drive Line Power Test versus the theoretical rolling resistance at the road for our rough estimate of rolling resistance. Note this chart has not been corrected for motor efficiency, so the actual driveline power loss at the road would be lower.

Future Tests:
Better results can be obtained in future tests by simultaneous measurement of time, velocity, current, and battery voltage. Vehicles used for the test should be weighed at the time of testing to avoid mass estimates. It would be very beneficial to utilize a photo-eye set up between 3 points, to record time coasting through a known distance.

It may be helpful to estimate the effects of tire pressure, and top up versus top down versus hard top by these methods.

A fifth wheel arrangement could be used to perform the test also, and we are in the process of finding a supplier.

counts 1	counts 2	time A	time B	Ave time	va1	vb1	v1	a1	Cw	f
33.59	26.87	10.12	9.94	10.03	50	40	45	0.997009	0.476313	0.016072
33.59	26.87	9.53	9.75	9.64	50	40	45	1.037344	0.542177	0.015545
33.59	26.87	9.53	10.94	10.235	50	40	45	0.97704	0.536737	0.013982
				9.968333	50	40	45	1.003177	0.519174	0.015163
					va2	vb2	v2	a2		
20.16	13.44	14.91	13.59	14.25	30	20	25	0.701754		
20.16	13.44	12.93	15.59	14.26	30	20	25	0.701262		
20.16	13.44	14.32	16.72	15.52	30	20	25	0.64433	top down	
				14.67667	30	20	25	0.681354		
				front tire, 34psi						
				rear....38pse						
				Frontal Area...1.0 m^2						
				Vehicle + driver mass: 376 kg						
			Air Density: 1.202 kg/m^3							

counts 1	counts 2	time A	time B	Ave time	va1	vb1	v1	a1	Cd	Croll
33.59	26.87	12.9	11.46	12.18	50	40	45	0.821018	0.430583	0.011832
33.59	26.87	13.25	12.13	12.69	50	40	45	0.788022	0.338807	0.013315
33.59	26.87	10.95	12	11.475	50	40	45	0.87146	0.512717	0.011095
				12.115	50	40	45	0.825423	0.425646	0.012086
					va2	vb2	v2	a2		
20.16	13.44	18.76	18.04	18.4	30	20	25	0.543478		
20.16	13.44	18.11	17	17.555	30	20	25	0.569638		
20.16	13.44	18.44	18.53	18.485	30	20	25	0.540979		
				18.14667	30	20	25	0.551065		
					Front tire: 34 psi					
					Rear tire: 38 psi					
					Frontal Area 1.0 m^2					
					vehicle + driver mass ...362 kg			(Jose)		
					Air Density: 1.202 kg/m^3					

Free roll energy usage tests for City-el

Data Date: 03/22/94

Equipment: Fluke Model 21 Series II Multimeter S/N 58570412

Sensitive Research Corp. DC Voltmeter Model C S/N 942135

In Car Shunt 0.33 mV/A

* Hydria :

Car 4135

Note: Negative means that the adjacent Watts are less than that being compared

Fwd Speed	mV	Battery V	Current I	Cruise Meter I	Watts	Diff. from 4127	Diff. from Rev.	Diff. from Series
5	0.9	38.0	2.7	2.0	103.6	-11.5	-10.0	
10	1.2	37.5	3.6	3.0	136.4	-13.3	-11.4	22.7
15	1.4	37.0	4.2	4.0	157.0	-24.8	-23.6	
20	1.9	37.0	5.8	5.5	213.0	-33.6	-22.4	21.1
25	2.3	37.0	7.0	6.5	257.9	-44.8	0.0	
30	2.6	37.0	7.9	8.0	291.5	-33.6	-11.2	11.2
35	3.0	37.0	9.1	9.5	336.4	-56.1	0.0	
>40	5.8	36.5	17.6	18.5	641.5	-34.8	-66.4	

Rev Speed	mV	Battery V	Current I	Cruise Meter I	Watts	Diff. from 4127	Diff. from Fwd.
5	1.0	37.5	3.0	2.5	113.6	0.0	10.0
10	1.3	37.5	3.9	3.5	147.7	-11.4	11.4
15	1.6	37.3	4.8	4.0	180.6	-12.6	23.6
20	2.1	37.0	6.4	6.0	235.5	-11.2	22.4
25	2.3	37.0	7.0	7.0	257.9	-22.4	0.0
30	2.7	37.0	8.2	8.0	302.7	-44.8	11.2
35	3.0	37.0	9.1	9.0	336.4	-45.5	0.0
>40	6.4	36.5	19.4	20.0	707.9	-12.1	66.4

Series Wound

Fwd Speed	mV	Battery V	Current I	Cruise Meter I	Watts
10	1.0	37.5	3.0	2.5	113.6
20	1.7	37.3	5.2	5.0	191.9
30	2.5	37.0	7.6	7.0	280.3
40	3.5	37.0	10.6	10.0	392.4

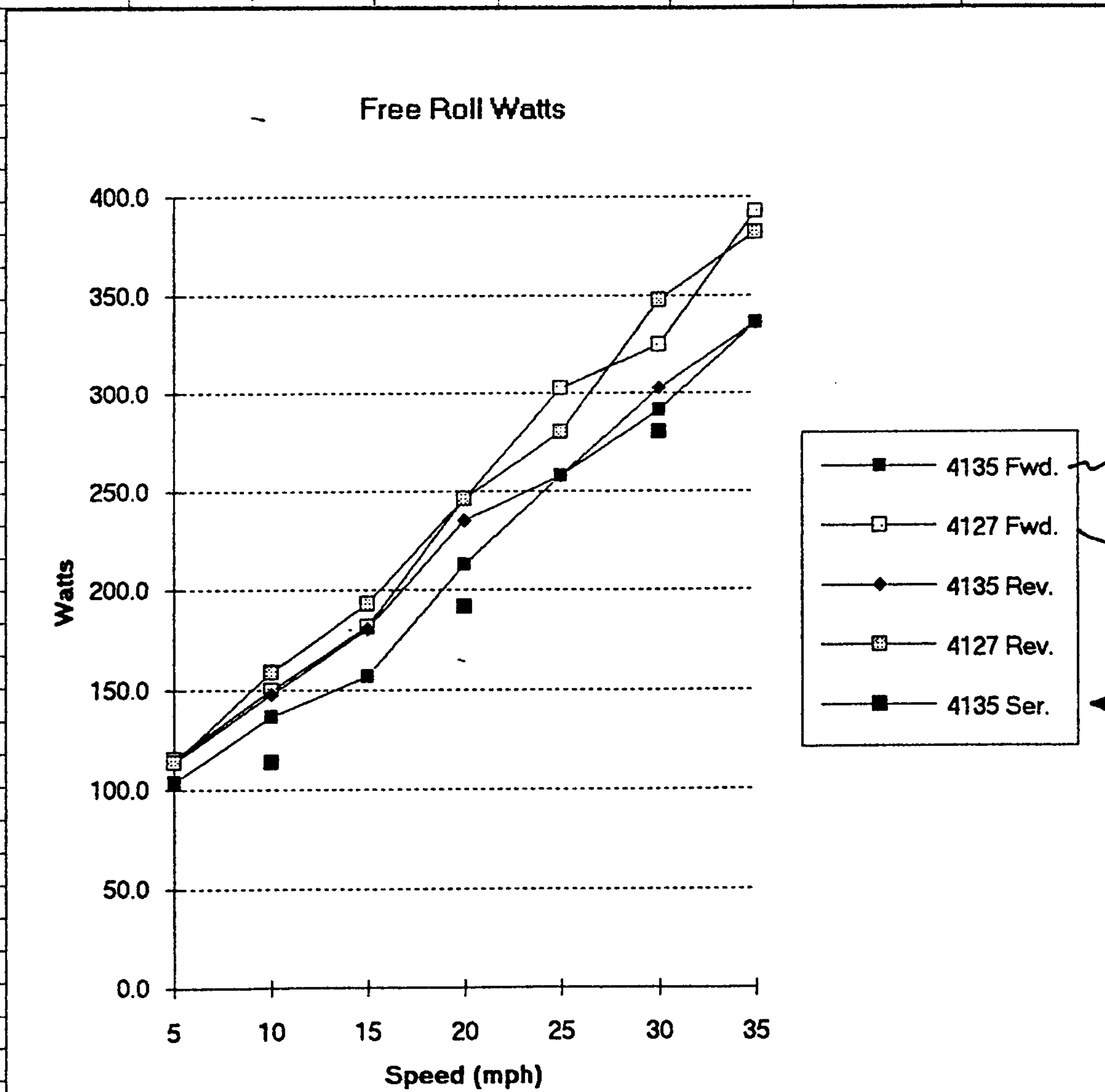
Car 4127

Note: Negative means that the adjacent Watts are less than that being compared

Fwd Speed	mV	Battery V	Current I		Watts	Diff. from 4135	Diff. from Rev.
5	1.0	38.0	3.0		115.2	11.5	1.5
10	1.3	38.0	3.9		149.7	13.3	-9.4
15	1.6	37.5	4.8		181.8	24.8	-11.4
20	2.2	37.0	6.7		246.7	33.6	0.0
25	2.7	37.0	8.2		302.7	44.8	22.4
30	2.9	37.0	8.8		325.2	33.6	-22.4
35	3.5	37.0	10.6		392.4	56.1	10.6
>40	6.2	36.0	18.8		676.4	34.8	-43.6
Hand Brake	14.0	36.0	42.4		1527.3		

Rev Speed	mV	Battery V	Current I		Watts	Diff. from 4135	Diff. from Fwd.
5	1.0	37.5	3.0		113.6	0.0	-1.5
10	1.4	37.5	4.2		159.1	11.4	9.4

15	1.7	37.5	5.2		193.2	12.6	11.4	
20	2.2	37.0	6.7		246.7	11.2	0.0	
25	2.5	37.0	7.6		280.3	22.4	-22.4	
30	3.1	37.0	9.4		347.6	44.8	22.4	
35	3.5	36.0	10.6		381.8	45.5	-10.6	
>40	6.6	36.0	20.0		720.0	12.1	43.6	
Chart Data on Watts								
Speed	4135 Fwd.	4135 Rev.	4135 Ser.	4127 Fwd.	4127 Rev.			
5	103.6	113.6		115.2	113.6			
10	136.4	147.7	113.6	149.7	159.1			
15	157.0	180.6		181.8	193.2			
20	213.0	235.5	191.9	246.7	246.7			
25	257.9	257.9		302.7	280.3			
30	291.5	302.7	280.3	325.2	347.6			
35	336.4	336.4		392.4	381.8			
>40	641.5	707.9		676.4	720.0			



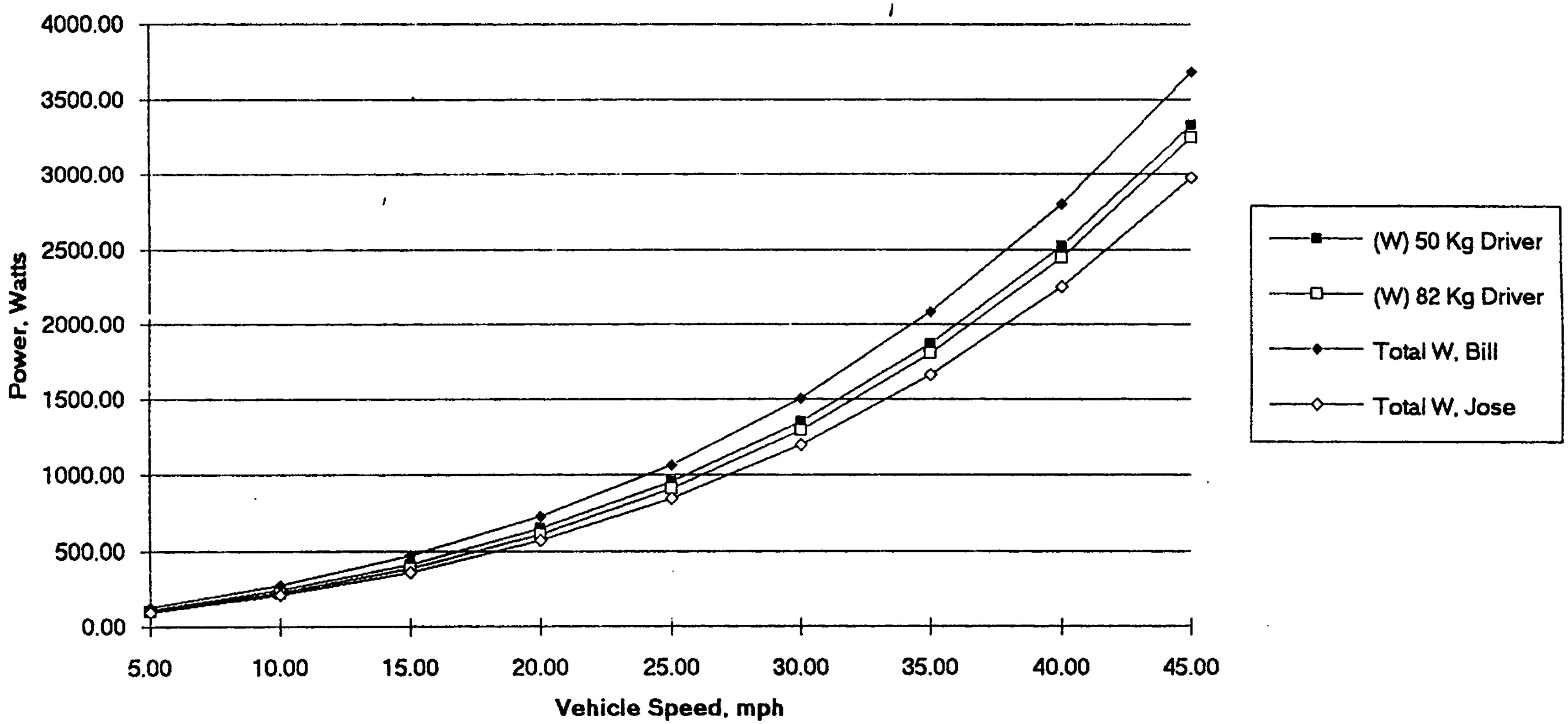
300mi + Hi

~100mi.

Series, compound unplugged

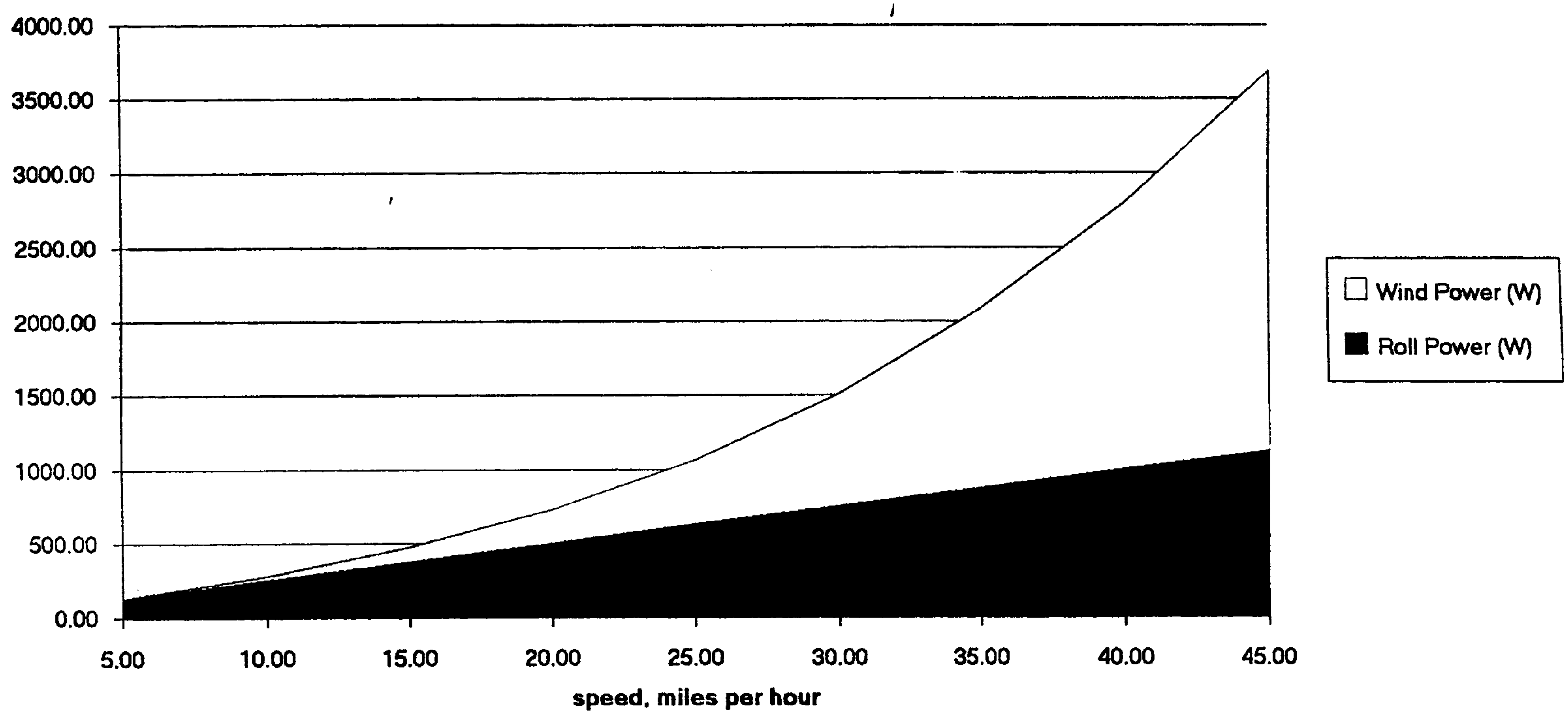
Vehicle jacked up.
power to spin drive.

Variation in Measured data versus the theoretical effect of Mass

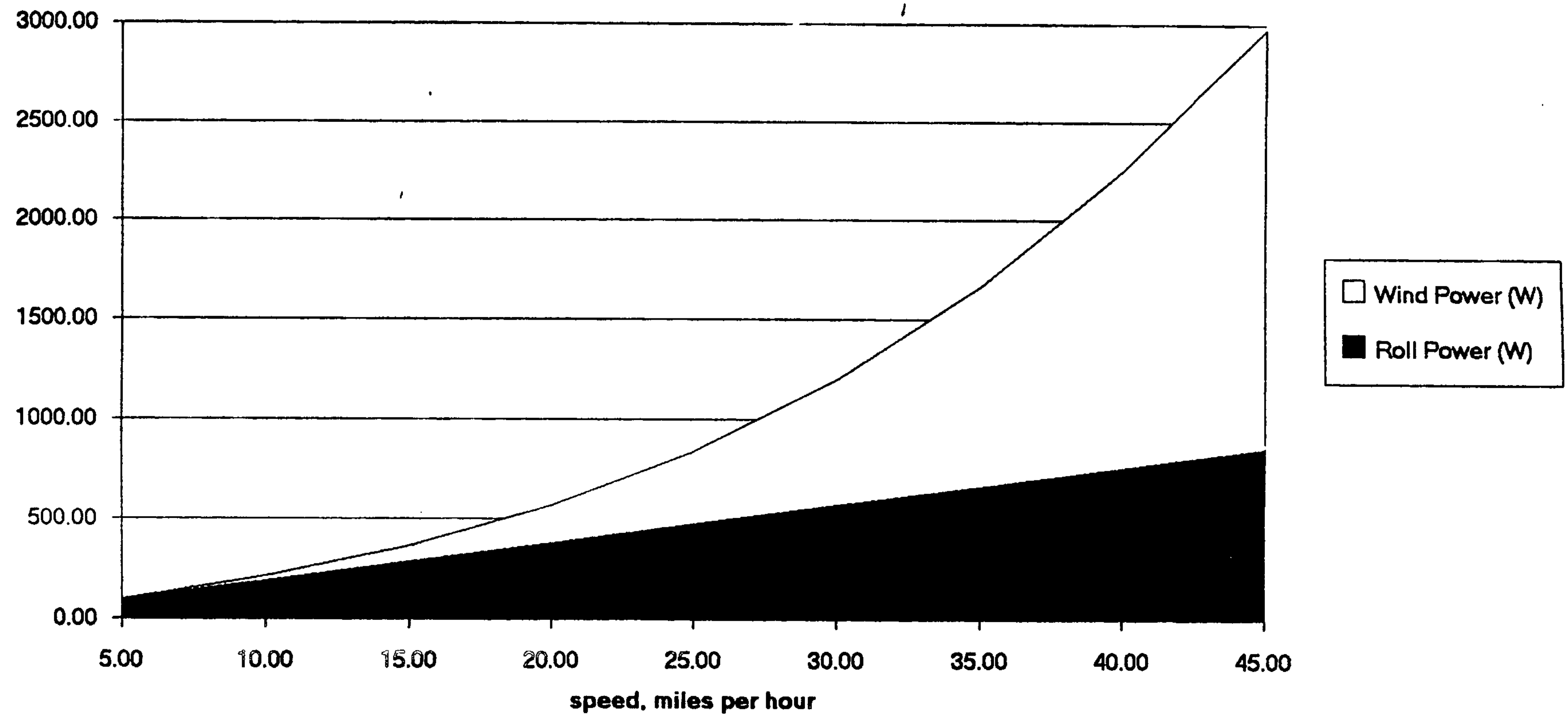


Rolling Resistance Plus Wind Resistance vs Speed, for City-el

BILL

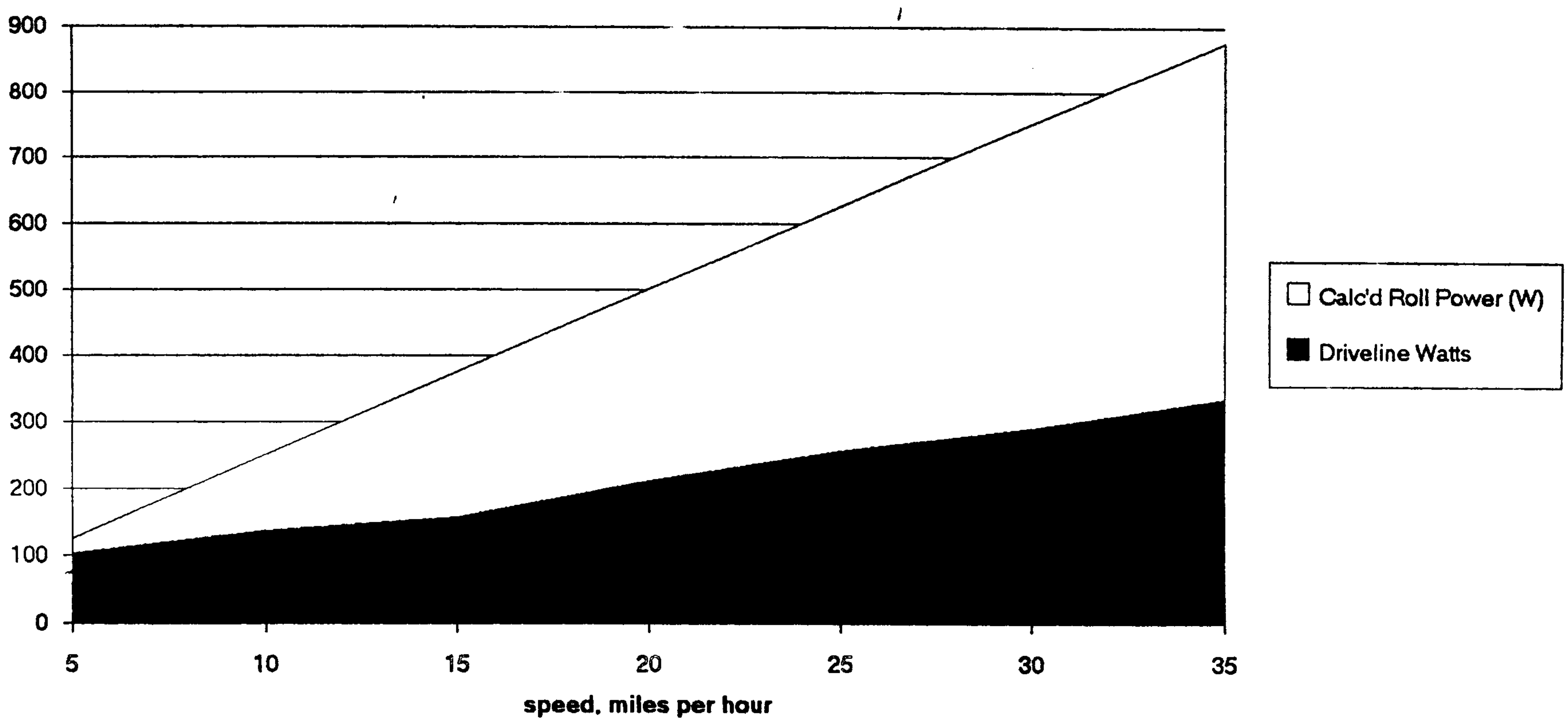


Rolling Resistance plus Wind Resistance vs Speed, for City-el   José



4/4/94

Estimated Drive Line Power Loss as a part of total rolling resistance, City-el



EXAMPLE CALCULATION.

Rolling Resistance & AIR DRAG : City-el

34 psi Front Tire 38psi Rear Tire.

Governing Equations: (Bosch Auto HNDBK 2ND edition, page 257)

$$V_1 = \frac{V_{a1} + V_{b1}}{2} \qquad V_2 = \frac{V_{a2} + V_{b2}}{2}$$

$$a_1 = \frac{V_{a1} - V_b}{t_1} \qquad a_2 = \frac{V_{a2} - V_{b2}}{t_2}$$

$$C_W = \frac{6m\,(a_1 - a_2)}{A(V_1^2 - V_2^2)}$$

$$f = \frac{28.2\,(a_2 V_1^2 - a_1 V_2^2)}{10^3 (V_1^2 - V_2^2)}$$

Experimental Values:

$V_{a1} = 50$ Km/h

$V_{b1} = 40$ Km/h $\quad \therefore V_1 = 45$ Km/h

$V_{a2} = 30$ Km/h $\quad \therefore V_2 = 25$ Km/h

$V_{b2} = 20$ Km/h

$t_1 = 9.968$ s

$t_2 = 14.677$ s

average of 3 tests both directions on same road.

$a_1 = 1.003$ Km/h·s $= 0.279$ m/s²

$a_2 = 0.681$ Km/h·s $= 0.189$ m/s²

$$C_w = \frac{6m(a_1 - a_2)}{A(V_1^2 - V_2^2)}$$

$m = 376\ Kg$

$A = 1.00\ m^2$

$V_1 = 45\ Km/h$

$V_2 = 25\ Km/h$

$a_1 = 1.003\ Km/h \cdot s$

$a_2 = 0.681\ Km/h \cdot s$

$\therefore C_w = 0.519$

at 200m elevation

$\rho_{AIR} = 1.202\ Kg/m^3$

$$f = \frac{28.2(a_2 \cdot V_1^2 - a_1 \cdot V_2^2)}{10^3 (V_1^2 - V_2^2)}$$

$a_1 = 1.003\ Km/h \cdot s$

$a_2 = 0.681\ Km/h \cdot s$

$V_1 = 45\ Km/h$

$V_2 = 25\ Km/h$

$\therefore f = 0.0152$

$F_{ROLL} = F_R = f m g$

$F_{AIR} = F_L = 0.5 \rho C_w A (V^2)$

$\rho = 1.202\ Kg/m^3$

$A = 1.0 m^2$

Analysis of Monthly Data

19 April, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared By: Lance L. Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

Analysis of Monthly Data

Purpose: This report presents a brief analysis of the data collected from the City-Els during the monthly service calls. This is part of the Neighborhood Electric Vehicle (NEV) program specified in SMUD Participation Agreement F-102 and as part of ARPA grant MDA972-93-1-0025.

Scope: Data from December 93 through March 94 is included in this report. The data collected on the City-Els included vehicle use as shown by the number of miles traveled, vehicle energy use at the plug, the number of days in the period, and needed repairs or problems. From these quantities, miles per day and Watt-hours per mile were computed. To date 32 City-Els are being used. The vehicles involved are distributed in the following manner. Twenty-five vehicles have been leased to McClellan AFB. Five vehicles have been leased to private customers. One vehicle at Drive Electric has been used significantly and one vehicle at Pacific Electric Vehicles has seen significant use for testing and promotional purposes. Three vehicle groups were made from the data. The first group included the data from all of the vehicles for which data sheets were taken. The second group included all 25 vehicles placed at McClellan AFB, and finally, the third group included all vehicles that logged more than 50 miles for the month.

Conclusions: From December 93 through the end of March 94 the program has accumulated 6767 miles. Not only has the entire number of miles traveled each month improved from 599 miles to 2256 miles but also the total number of miles traveled by vehicles with more than 50 miles each month has improved from 194 miles to 1892 miles. City-El 3992 leased to McClellan AFB has the best efficiency traveling 469 miles while using 0.2797 kWh per mile during the month of March 94. On average however, McClellan AFB City-Els average 1.09 kWh per mile and 141.9 miles per month. This is reasonable since base personnel have been instructed to leave the vehicles plugged in. With a holding charge of 50 Watts, the charger can use 1.2 kW per day without the vehicle even being used. There is some concern about the accuracy of the Watt-hour reading. Recent tests show that the Hydria Watt-hour meter in the vehicles may read 10% too high. The exact error has not yet been determined, and the data has not been corrected for this. The most serious repairs so far have involved three transformer failures.

All City-Els Group:

This group serves as the starting point to determine which vehicles have been used significantly. In December 93, this group included 26 vehicles and as of March 94 involved 32 vehicles. Since this group occasionally includes vehicles with no mileage, the averages are not particularly useful. The attached graph Total Miles Logged Each Month by All City-Els does show the increasing use of the City-Els each month from 599 total miles in December 93 to 2256 total miles in March 94. Keep in mind that the line showing City-Els in Service shows all City-Els with data sheets. For the month of March, several unused vehicles at Drive Electric and Hightower Associates had service checks.

McClellan AFB City-Els Group:

From December 93 through March 94 the 25 McClellan AFB City-Els have accumulated a total of 3547.9 miles using a total of 3250.860 kWh. They have averaged 1.094 kWh per mile and 141.9 miles per month or 1.4 miles per day. This level of energy use is understandable since base personnel have been instructed to leave the City-Els plugged in. The charger can draw as much as 50 Watts during the holding charge. This means that 1.2 kWh can be used each day without driving the vehicle. Furthermore, base personnel have been instructed to limit City-El use during inclement weather. Since the last few months have had periods of rain, the vehicles have probably been sitting for several days at a time.

High Mileage City-Els:

High mileage City-Els are those vehicles that log more than 50 miles in a given month. The 50 mile cutoff was chosen because it represents a theoretical minimum commute of 2.5 miles round trip 5 days a week. This is an interesting group because it includes only those vehicles with significant use. The averages obtained therefore are more representative of the values to be expected when private individuals use the vehicle. In fact, the private individuals leasing City-Els have consistently fallen into this group. During December 93, only 2 vehicles fell into this group, but during January 94 the number increased to 5. A large increase to 11 vehicles occurred in February 94, and for March 94, a total of 12 vehicles were driven more than 50 miles during the month.

High mileage City-Els for the month of March 94 logged 1892.3 miles while using 841.422 kWh. On average, they used 550.7 kWh per mile and covered 157.7 miles per month or 5.9 miles per day. Totals from December 93 to March 94 are not particularly meaningful for this group because a vehicle may drop in and out of the group. Therefore a total computed with this vehicle would include times when it did not cover more than 50 miles in a month. It is for this reason that the March 94 results are given above rather than the totals.

For the high mileage City-Els, the following graphs are attached at the end of this report.

Total Miles Logged Each Month by High Mileage City-Els
Average Use Each Month for High Mileage City-Els
Average Energy Use Each Month for High Mileage City-Els
Average Energy Use per Mile Each Month for High Mileage City-Els.

These graphs show the trends in total miles, average miles, average energy use, and average energy use per mile for each month. In addition to showing the trends in these quantities over time, each graph also shows how many City-Els were included in the high mileage group each month. A review of these graphs shows several things. First, there has been a significant increase in the number of miles logged each month as part of this group, and there has been a steady increase in the number of vehicles included in this group. Total miles each month went from 194 miles in December 93 to 1892 miles in March 94 while the number of vehicles increased from 2 to 12 over the same time period. Second, there has been a general increase in the average number of miles logged each month by the

vehicles. December 93 had an average of only 97.2 miles per City-El. March, however, had an average of 157.7 miles per City-El. Third, the average energy use for the month has fluctuated around a fairly constant value of about 65 kWh. The high was 71 kWh in January 94 and the low was 55 kWh in December 93. Since December included only 2 vehicles, February 94 may be a more representative low at 57 kWh. Fourth, as would be expected based on the previous two graphs average energy use per mile has dropped particularly from January 94 to March 94. During that time period, the average fell from 0.8057 kWh per mile to 0.5507 kWh per mile. December's data is low but may not be very representative since only 2 vehicles were included that month. This shows that driving the vehicles more lowers their energy use per mile.

Scatter plots of energy and distance of high mileage City-Els for January, February, and March 94 are also attached. December 93 was not attached since it only included 2 City-Els. These plots clearly show that the City-El becomes more efficient when it is driven further. This is primarily due to increases in charger efficiency during the main charge and a reduction of holding charge time. There is a noticeable drop in energy use per mile when the vehicle exceeds 100 miles in a month. The reason for this may be that those vehicles over 100 miles per month are predominantly used by private individuals. As mentioned before, McClellan AFB personnel leave the vehicles plugged in at all times and have typically been logging less than 100 miles in a month. The most efficient vehicle to date however was 3992 leased to McClellan AFB. For the month of March 94, it traveled 469 miles using 0.2797 kWh per mile. The least efficient vehicle in this group was 4132 leased to McClellan AFB. It went 54.5 miles and used 1.06 kWh per mile in the month of January 94.

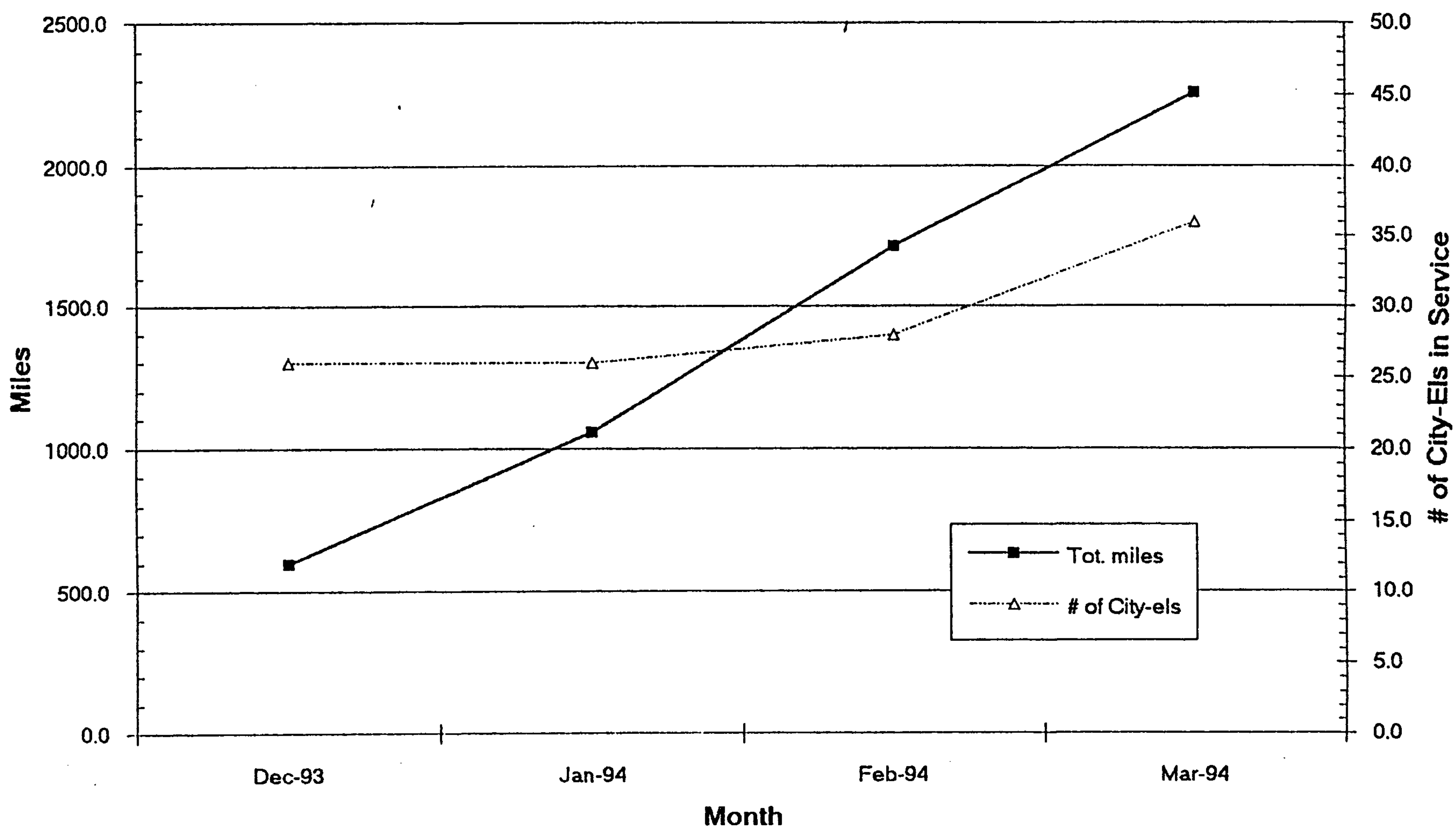
Instrumentation Accuracy:

Recent tests indicate that the Hydria Watt-hour meter installed in each vehicle reads approximately 10% too high. The exact magnitude of the error has not yet been determined. Therefore, the data used in this analysis has not been corrected for this potential error. The mileage data was taken from the vehicle odometer. No testing has been done to measure the accuracy of the odometers or the amount of variation between different vehicles.

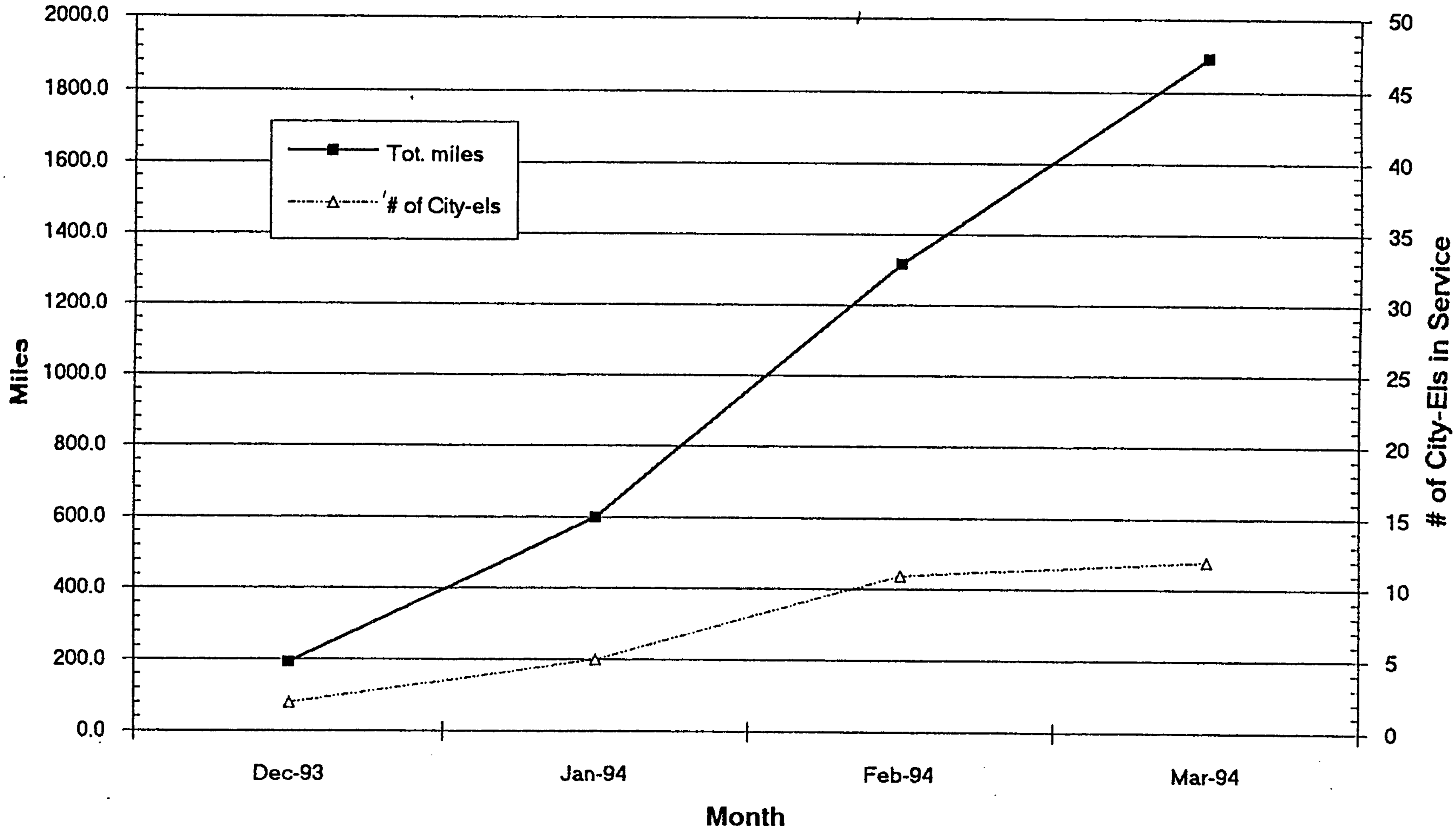
Repairs:

A list of repairs and problems with the City-Els is attached at the end of this report. This list is sorted by type of problem. To date, the most common problems are as follows. Three snaps have come off the canopies. Three hub caps have been cracked or broken and two needed new hub cap grommets. Three transformers have had failed shortly after being installed and there have been a variety of problems with the turn signals and brake lights. There has also been some vibration problems with the front wheel.

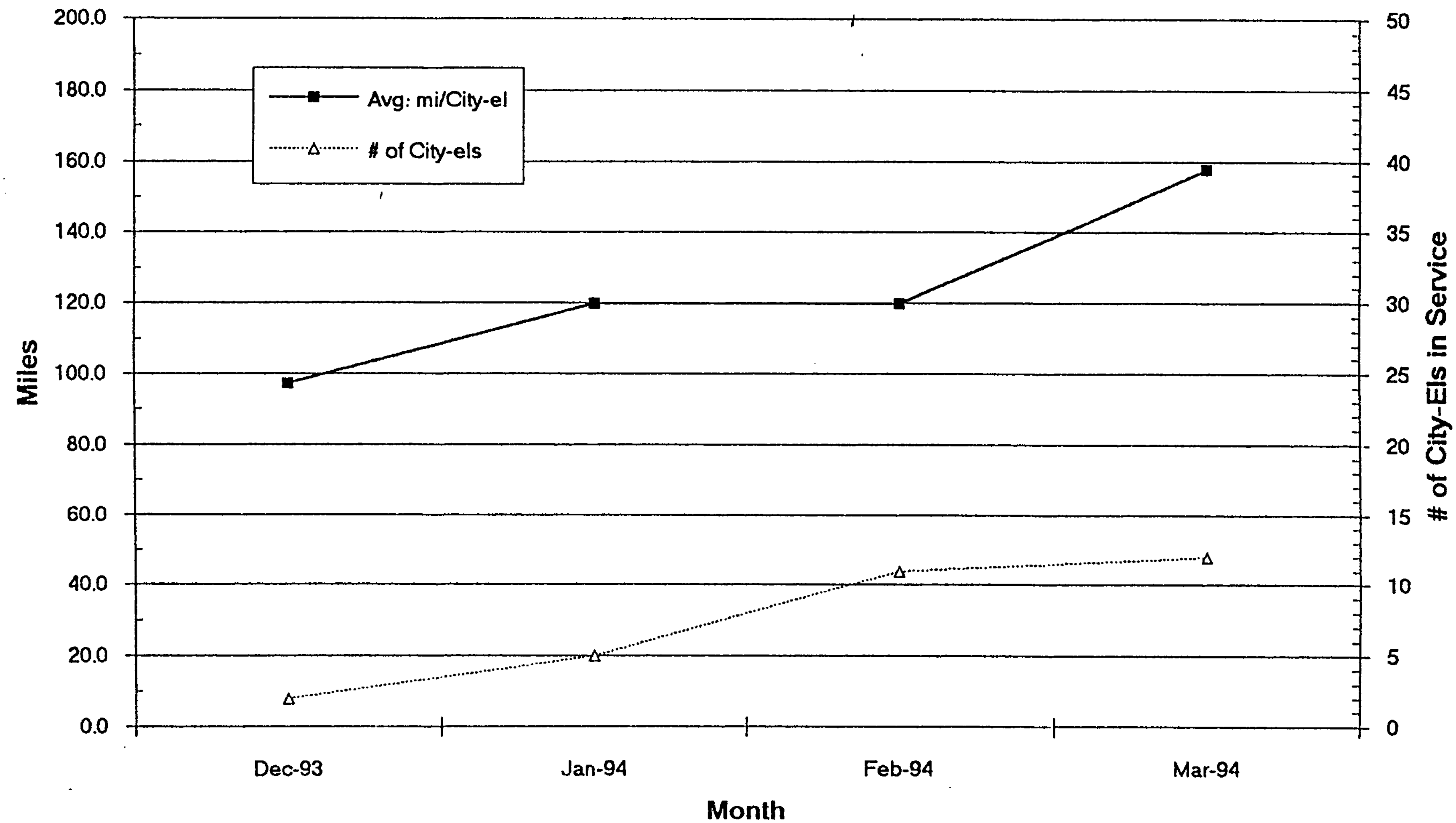
Total Miles Logged Each Month by All City-Els



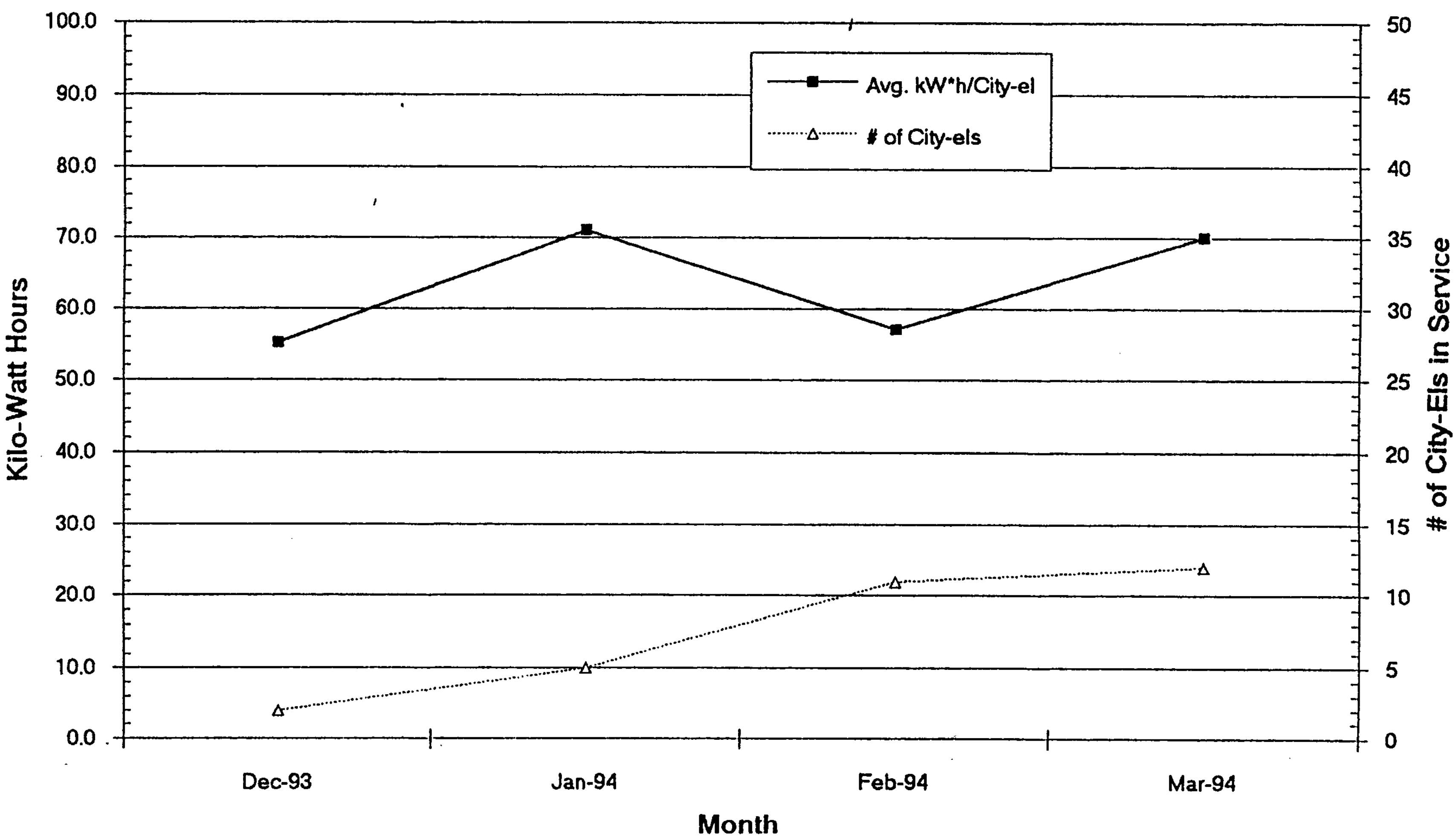
Total Miles Logged Each Month by High Mileage City-Els



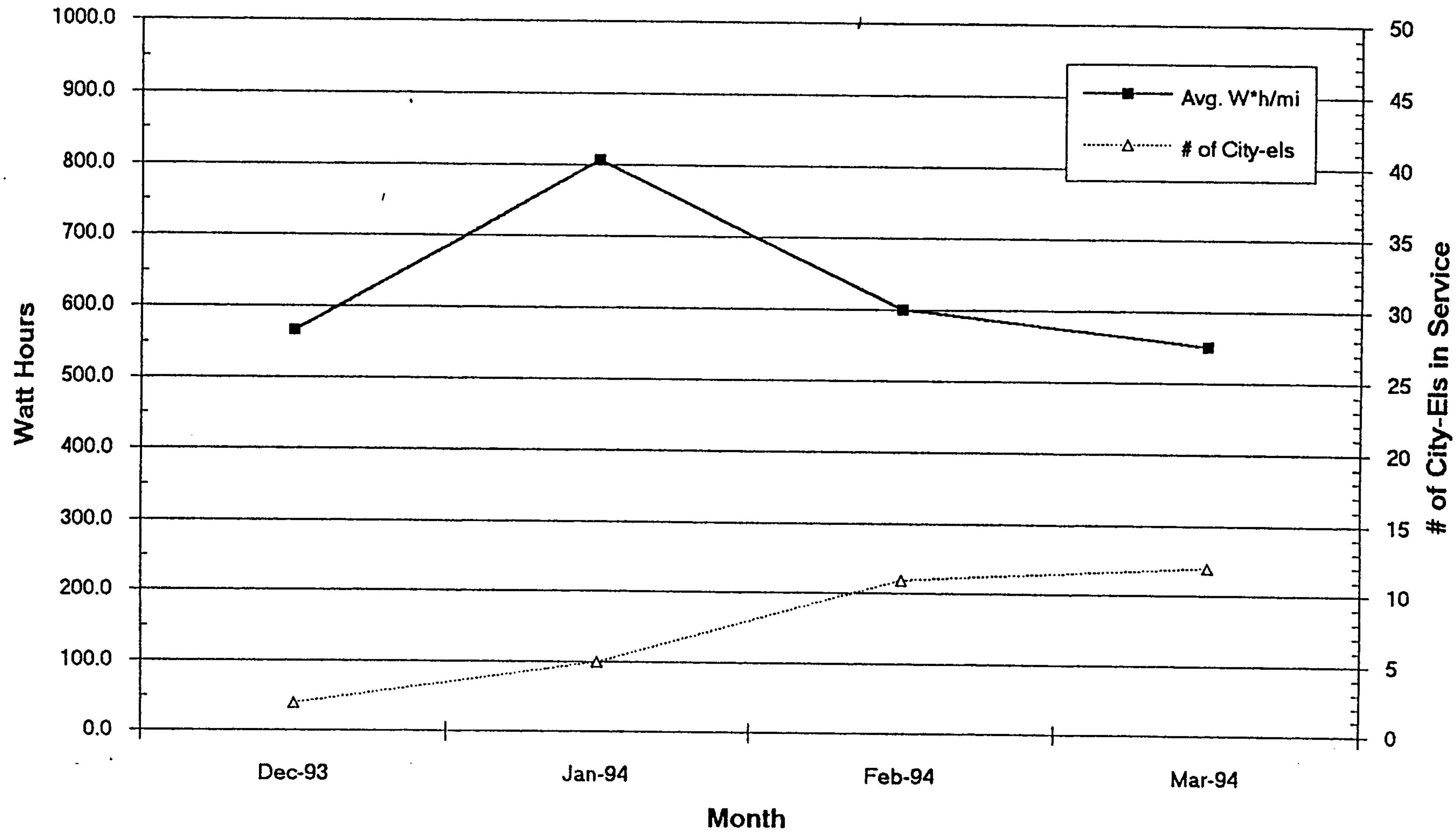
Average Use Each Month for High Mileage City-Els



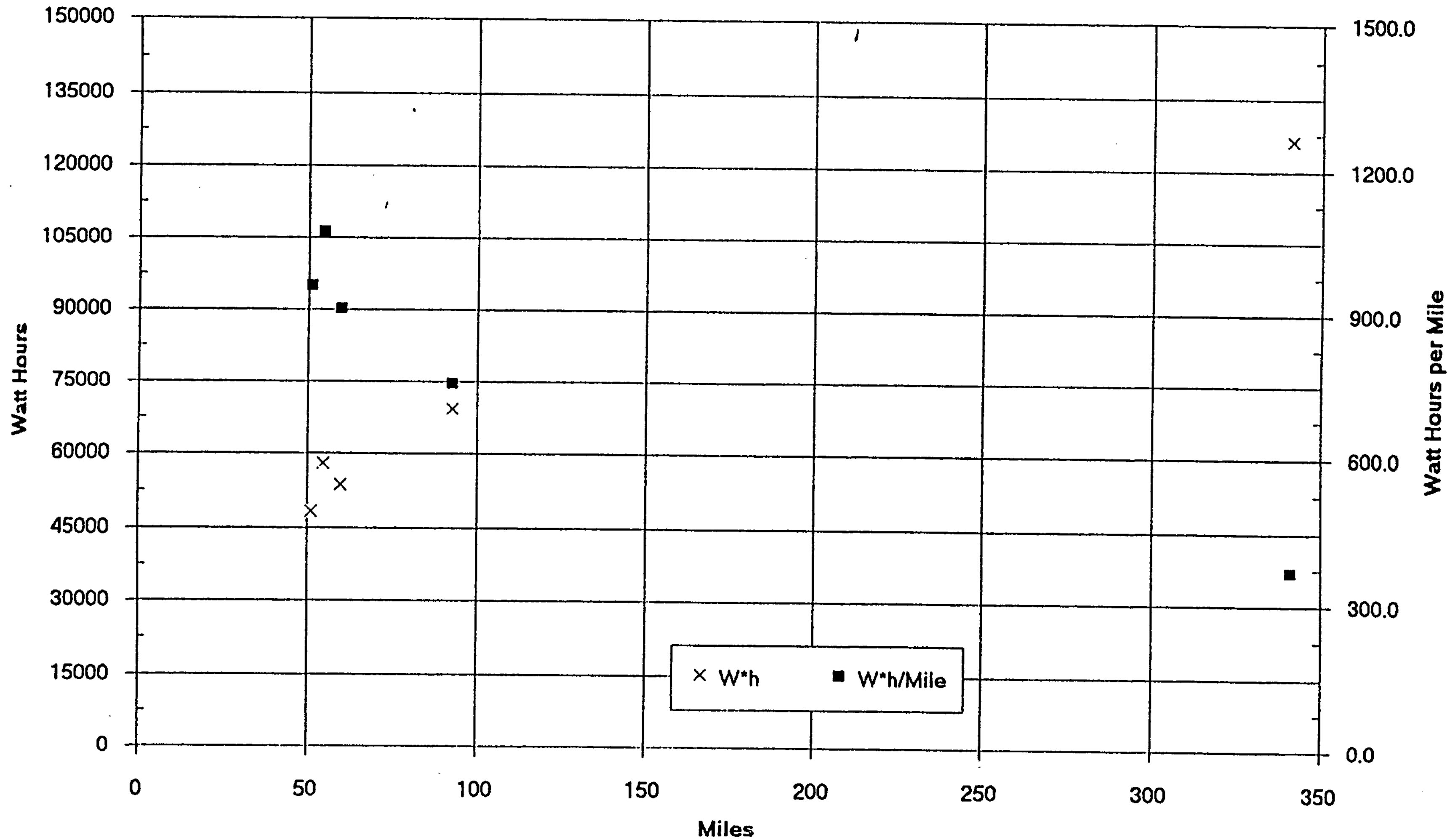
Average Energy Use Each Month for High Mileage City-Els



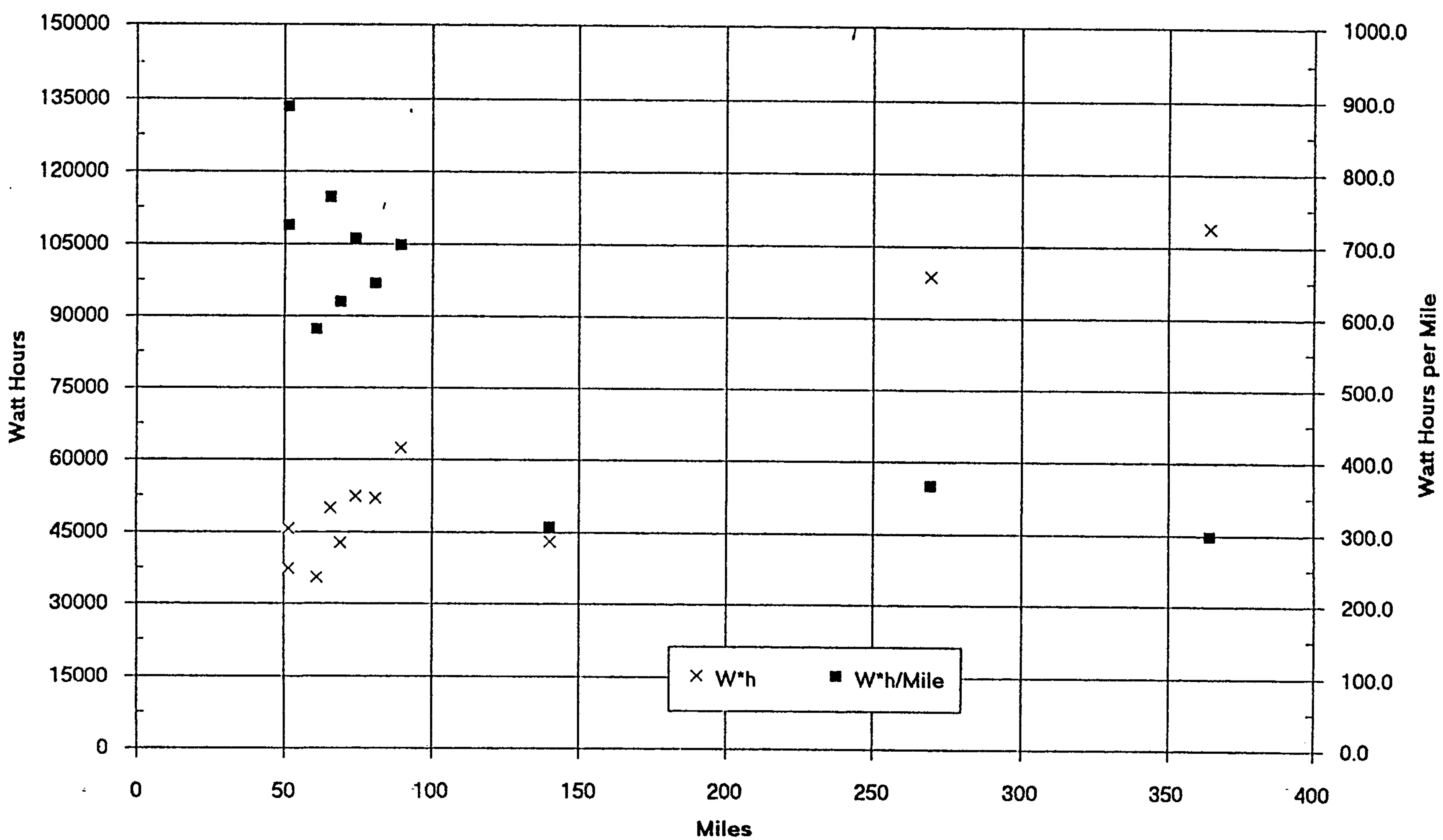
Average Energy Use per Mile Each Month for High Mileage City-Els



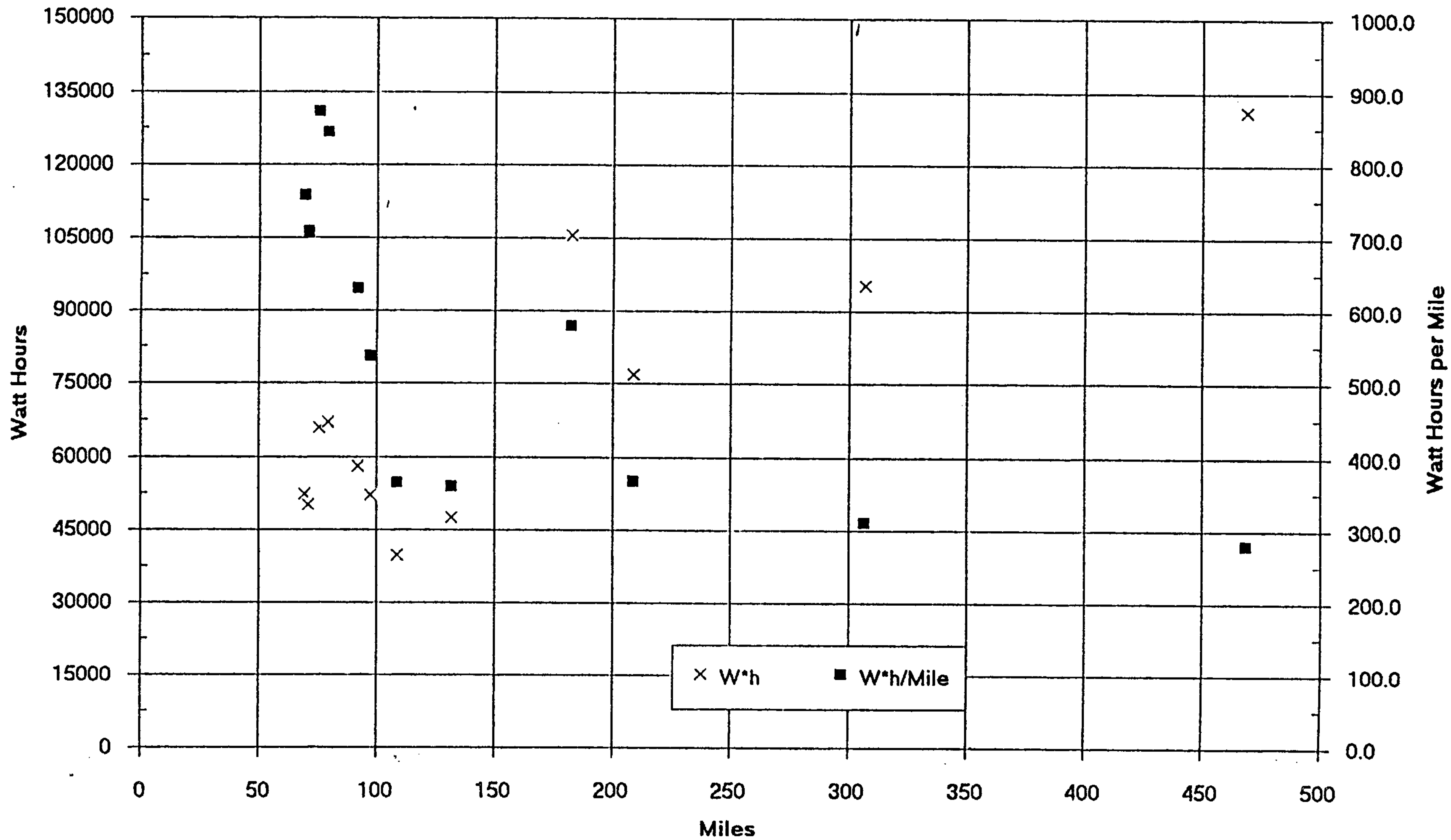
January 94 Energy and Distance Scatter Plot for High Mileage City-Els



February 94 Energy and Distance Scatter Plot for High Mileage City-Els



March 94 Energy and Distance Scatter Plot for High Mileage City-Els



Repair List for City-Els

ID #	Date	Mileage	Repair
3997	3/8/94	149.3	Battery cable melted down due to a loose bolt.
4155	3/16/94	100.6	Battery had a very loose terminal on negative terminal of middle battery.
4131	3/16/94	139.5	Belt slips in wet weather.
4152	3/16/94	190.4	Brake fluid weepage on floor mat.
3999	2/16/94	87	Brake light on left wouldn't work due to a wiring short.
4129	3/23/94	415	Brake lights out due to bad micro switch.
3993	3/23/94	208	Brake vibration in front.
4030	3/17/94	1031.1	Brake vibration in front.
4152	3/16/94	190.4	Canopy cracked on left side.
4139	1/18/94	56.3	Canopy latch adjustment needed.
4153	3/16/94	237.3	Canopy latch adjustment.
4152	3/16/94	190.4	Canopy snaps have come off.
4130	3/16/94	105.3	Canopy snaps have come off. Two of them.
4142	3/8/94	0	Horn button won't stay in.
3993	2/15/94	25.5	Hub cap broken
4135	3/25/94	260.8	Hub cap cracked on left.
4029	1/18/94	35.8	Hub cap cracked.
3991	3/16/94	101.5	Hub cap grommet needed
4030	3/17/94	1031.1	Hub cap grommet needed.
4131	1/18/94	59.8	Power intermittent with key on.
3996	2/16/94	114.1	Pulley runout frayed belt edge. May also have been installed wrong.
4131	3/16/94	139.5	Seat belt is difficult to unreel (customer comment).
4139	1/18/94	56.3	Seat grommets needed.
4155	1/18/94	76.6	Seat grommets needed.
4155	1/18/94	76.6	Speed kit connector needed fixing
3993	11/16/93	5.4	Transformer failure of pins and connector
4125	11/19/93	4.6	Transformer failure.
4131	12/29/93	59.5	Transformer failure.
4029	12/15/93	25.1	Turn signal on right front out.
4134	3/16/94	109.4	Turn signal switch doesn't go left without considerable force.
3992	2/3/94	34.7	Turn signal wire under the dash broken
4137	3/18/94	66.9	Window release gasket for right window was pulled out.

Component Test Plan

Neighborhood Electric Vehicle Product Test and Development Project

26 July, 1994

Prepared by: W.R.Warf Pacific EV

This Project is sponsored by ARPA under grant MDA972-93-11-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

1.0 Purpose and Goals:

The purpose of the Component Tests is to allow comparison of various components in the context of a Neighborhood Electric Vehicle. Tests will be accomplished in such a way as to allow comparison of test data to vehicle use data. The goal is to be able to select the best components for use in a new production NEV. The best components and systems for NEV application will be determined on the basis of performance, weight, efficiency, quality, reliability, availability, and price.

Our goal is to identify combinations of components which, when combined into a vehicle system, will achieve the lowest initial cost plus the lowest energy use and the best total life cost of the system. Low energy use is important in an NEV because of the relatively small battery pack size and the low cost goals of the program. Narrowing the choices between components and systems will be possible once test data and DAS acquired vehicle use data is in hand, by analyzing the data.

The goal of the information gathered from component testing is to be able to support system and component selection with experimental data. The information gathered will be evaluated in terms of improvement relative to the key components and systems used in the City-el system. The systems in the City-el are assessed to provide a baseline for comparison.

2.0 Scope:

This Component Test Plan outlines the scope of work needed to accomplish the above purpose and goals. The specific tests to be performed are identified. The rationale for each test is discussed. The type of documentation to be produced before conducting the test, and following test completion is defined.

For the purposes of this plan, the vehicle systems are divided into four groups, consisting of four system boundaries, which are as follows:

a) Mains-Charger-Batteries.

b) Batteries - controller - Motor

c) Motor Torque to Driving Force Conversion

d) Auxiliary Systems (Batteries, DC-DC converter, loads)

The systems in the City-el have been preliminary characterized in terms of energy use per average mile traveled for the above systems a) through c) above. Tests to develop this data are documented, please see the referenced document list, paragraph 8.0 of this document. The results of this characterization are shown in Figures 1 and 2. A test is underway to assess the auxiliary system on the City-el. Ongoing measurements taken manually and by the Data Acquisition System will provide additional data regarding the City-el.

In the following plan, system tests and documentation are outlined for each system. In general, power in, power out, time, temperatures, and losses will be measured in each test. A written assessment of the each component within the system will be prepared according to Figure 3. A discussion of the test plan for each system follows.

2.0 Mains - Batteries - Charger

The batteries used in an electric vehicle have a significant impact on the cost effectiveness of the system. There is a desire to use ever higher system voltages to minimize Joule heating and to reduce current draw from the battery pack for a given power level. Lower currents should increase battery life. The disadvantage of higher voltages is in the number of batteries needed, and the resultant cost of pack replacement. In addition, there is evidence that when the charger used senses the bulk voltage of the pack on longer strings of batteries, the batteries may be inadequately charged because of variations in cell voltage along the string at the equalizing or gassing point . This may result in reduced battery life in higher voltage systems that do not apply a BADICHEQ type system which measures each battery, and directs power to the batteries which need more charge, as opposed to sensing pack voltage. Since a BADICHEQ system would add unnecessarily to the cost of an NEV, an acceptable maximum system voltage will be estimated through the test described in 2.1. Battery tests are effectively in progress, and are documented by the monthly use data and DAS data. Additional Charger efficiency tests are described in paragraph 2.2.

2.1 Battery Voltage Variation at the Gassing Point:

A test procedure will be written which provides for measurement of the voltage on each battery in a string of batteries during charging with a charger which measures bulk pack voltage as a means of adjusting the charge algorithm. This procedure will provide for measurement of 36 Volt, 60 Volt, and 96, 120, or 144 volt systems using 12 volt batteries. The procedure will also provide for recording of power in, power out, bulk voltage, and battery temperature. Tests will be performed on 3 of the above system voltages on existing vehicles. Identical tests will be performed on these same systems 3-6 months after the initial test. The

variation in battery voltage will be compared to manufacturer's suggested charge profiles, and the extent of variation estimated as a function of system voltage.

2.2 Charger Efficiency Tests:
The efficiency of the charger is significant when total vehicle life cost is considered. Each of the above Battery Voltage Variation tests will provide charger efficiency data. In addition, we will have ongoing systems tests recorded by the DAS and manually for City-el chargers in four forms which are:
OEM, tuned for GNB, tuned for Sonnenschein, and tuned for Teledyne Batteries.

2.2.1 Charger tests will also be performed on the following, budget permitting:
a) a solid state, high frequency charger (Solectria or ?)
b) American Monarch, 36 V
c) American Monarch, 60 V
d) Quick Charge, 36 V or 48 V
e) other chargers in SMUD inventory as time permits.

2.2.2 Each test will be performed according to a standard charger efficiency test procedure, which prescribes the test record. The ability of the chargers to adjust equalizing and holding voltage temperature compensation curves as provided by battery manufacturer's will be established.

3.0 Battery-Motor-Controller system tests:

Motor Controller systems for the new NEV should be as efficient as possible throughout the driving range. The maximum possible low speed torque should be combined with a reasonably high maximum speed, and maximum efficiency. The tests proposed will include bench and in vehicle tests of brushed and brushless motors to determine the value of the higher priced DC brushless servo motors. While it would be very good to test a small induction motor, we are presently not aware of systems available in the voltage, power, and price range needed.

The following motors- controller combinations will be tested:
Advanced DC + Curtis
Solectria Brush + Solectria
Solectria Brushless + Solectria
Inertial Motor + Curtis
Lynch + Curtis
City-el Thirge Titan + Curtis

For each motor, both an in vehicle test and a bench test of the system will be performed. Motors and controllers must be tested at their design voltage, which in the case of the Solectria components amounts to 60 V for the brush permanent magnet, and 72 V for the brushless.
The higher voltage systems will be installed in four wheeled development platforms for comparison with Thirge Titan-Curtis four wheeled platforms. An additional controller which offers regenerative braking should be acquired and tested with some of the above motors.

3.1 Bench Tests, Batteries-Motor Controller-Motor
Budget permitting, each of the above motor controller combinations will be dynamometer tested for the purpose of creating torque-speed-efficiency maps. These maps provide information about the motors out-put under part load at a range of speeds, and at full load at a range of speeds. The test procedure written to describe the tests will take into account the "average trip" data acquired from DAS installed in City-el's. The test procedure will be written by the laboratory in possession of the dynamometer. Data shall be included to determine the temperature constants of the motor, and the rate of temperature rise at various loads and currents. Power out divided by power in will provide efficiency. A battery bank at the design voltage for the motor controller will be used for the power supply. The age, number of cycles, and the temperature of the batteries shall be recorded during the test. It is desirable to measure the frequency of the controller as well as recording controller out-put wave form descriptions during these tests if this is possible.

3.2 'In Vehicle' motor+controller tests
Each of the above motor controller combinations will be installed in a City-el or in a four wheeled development chassis. Energy use, power profiles, and associated data will be gathered with the Data Acquisition system or manually to compare the systems. These tests are important because in vehicle reliability assessment is possible. Logs will be kept of the energy use per mile, for comparison to other City-el data.

4.0 Motor Torque to Driving Force conversion
These tests are performed in roll down tests between certain points on the road, and by jacking up the vehicle and measuring the force to drive the wheels. This is best performed between two photo eyes, which is preferable if budget is available for the equipment. A significant amount of data will be recorded using the DAS, which will compliment the report in document described in paragraph 8.3 of this document. During the prototype development phase, similar tests will be performed on chain drives, other belt drives, and on differentials, to determine the efficiency relative to the belt drive used in the City-el.

5.0 Auxiliary Systems:

The DC-DC converter providing for lighting and other 12 V loads is an important element in the EV system from a cost standpoint, and at some loads from an energy use standpoint. These tests will characterize the range of loads seen by the 12 V system in a City-el, as well as the efficiency of the DC-DC converter. We have acquired a Solectria DC-DC converter for a 60 V system, which will also be characterized under similar loads.

It would be beneficial to test Sevcon and Curtis DC-DC converters in the 36-48-60 volt range, budget permitting.

6.0 Test Procedures

Test procedures will be written by the group performing the test to develop test information outlined in this plan. Test plans and test procedures require approval by PEV, and may require approval by SMUD. Where components are purchased by SMUD for the test, SMUD must approve the test procedure prior to component purchase. A good test procedure provides a detailed, chronological sequence of the test events, as well as a list of measurements to be taken, the equipment to be used, Calibration or comparison methods for instruments, and a ready to fill out data sheet. It is the intent of this Test Plan that the same Test Procedure will be used for the different combinations of components within each system boundary described above.

7.0 Test Reports:

Test reports shall be thorough enough to allow a meaningful repetition of the test with a different component at a later date, and direct comparison of the values measured. Thorough descriptions of the test equipment, repetitions or calibrations to establish how good the set-up is, a thorough description of test method shall be provided. If the test procedure needs revision, the parties involved in approving the procedure shall approve the revision before implementation of the change.

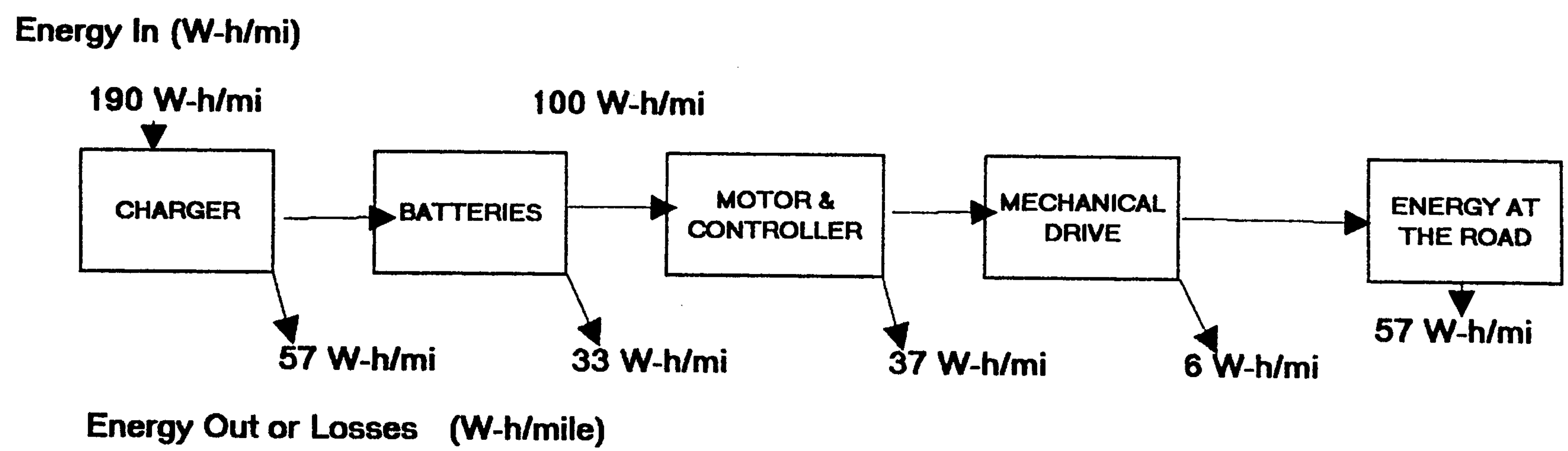
Each test shall be done with a written data sheet or log that describes the sequence of the test and the variables to be recorded. Sometimes we can make the data sheet while doing the first test, but we should follow the same sequence and method for subsequent tests. This will allow comparison of components in a systematic way while minimizing concern for the relative validity of the numbers from different tests. This will help make the variations in our test results and reports explainable. Who did the test and the test date shall be recorded.

8.0 Referenced Documents:

8.1 "City-el Charger, Tuned for GNB Batteries", by PEV dated 10 June, 1994
8.2 "Test Report, Charger Efficiency of the City-el Charger", by PEV, dated 30 March, 1994
8.3 Rolling Resistance and Coefficient of Drag Testing, City-el electric vehicle", by PEV, dated 12 April, 1994
8.4 SMUD McClellan NEV Program, Technical Overview, Presentation Materials by Jose Baer and Henning Bitsch, dated 5/11/94

FIGURE 1. COMPONENT TEST PLAN

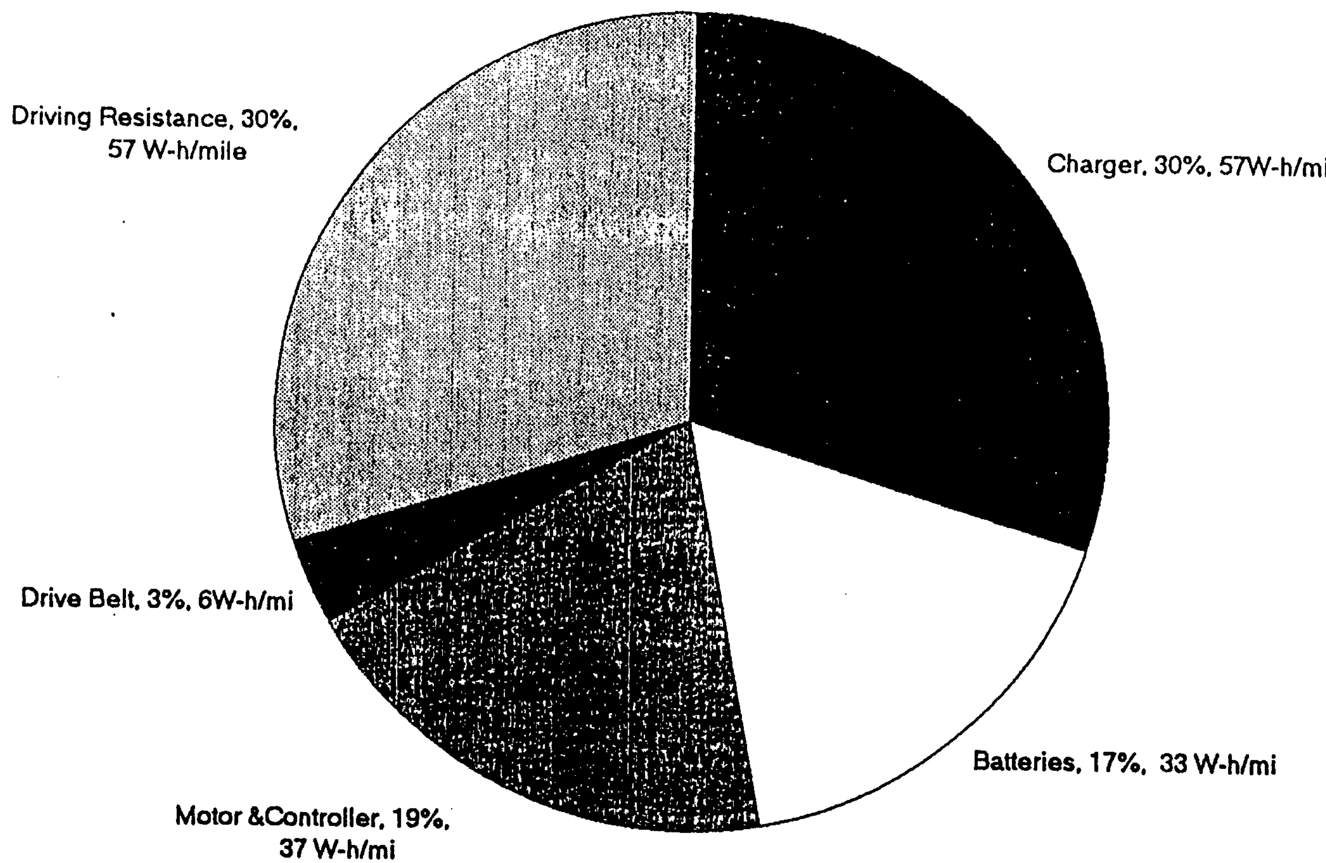
City-el, Average Energy Use of Main Systems



Note, Neglects holding charge and "always on" losses

FIGURE 2 COMPONENT TEST PLAN

City-el Systems Energy Use, Average per mile traveled, 190 W-h/mi total at plug



PEVCELENRGY.XLS Chart 16/28/94

Component description: Component Owned by:
Manufacturer Manufacturer's Address & Phone:
Name Plate Data (record all): Rated Voltage Rated Current Min/Max voltage Power Limitations other
COMPONENT COSTS:
1EACH 10 EACH 100 EACH PURCHASE AGREEMENT FOR 1000 pcs.
Component Weight:
Describe Materials of construction:
DescribeConstruction:
Supplier Quality Data:
Mean Time Between Failures: Years in Production Number of Units produced: Service Intervals Warranty:
Patents?
DATES TESTED AND TEST REPORT INFORMATION:
Notes: 1. For chargers, record manufacturers power factor information.

Test Report, Solectria Force Charger and Battery Test.

31 August, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

TEST REPORT: Solectria Force Charger and Battery Test.
Prepared by: Lance Atkins, Pacific Electric Vehicles, 8-31-94

Purpose:
This report documents the efficiency and performance of the Solectria solid state charger. This was done to compare the performance of the Solectria charger with the performance of the City-el charger. It gives some idea of how much a Neighborhood Electric Vehicle (NEV) might benefit from a solid state charger. This also explores the variation of individual battery voltage in long strings of batteries and what that variation might do to battery capacity and life. This should provide information to aid in choosing a pack voltage for an NEV.

Scope:
The test set-up, measuring equipment, and test procedure for the charge and discharge tests are discussed below. Explanations of the spreadsheet quantities and attached graphs is provided. Results are also given.

Results:
The Solectria charger appears to be quite good in terms of the charge profile selected and in terms of efficiency. Its current drops sharply after its chosen gassing point, and the average efficiency is 93%. The voltage variation from battery to battery reaches a maximum of 0.58 volts just before the end of the charge. This variation appears to affect the battery capacity as measured by the specific gravity and as measured by the discharge tests.

Test Initial Conditions.
This test was performed at Pacific Electric Vehicles on Solectria Force batteries. The original Trojan 27 TMH batteries were removed from Solectria Force 2C1MR2465R6701233 on 8/3/94. One thousand nine hundred and forty-six (1946) miles were on the vehicle at the time the batteries were removed. Unfortunately, the discharge history of the batteries previous to their removal was unknown.

Charge Test Procedure
This portion of the test was conducted over the following time period. The initial specific gravity test was performed at 8:45 AM on 8/8/94. Final preparations for the charge test were completed and the test was begun at 9:32 AM on 8/8/94. About 9.5 hours later the test ended at 6:45 PM on 8/8/94. The next morning the ending specific gravity readings were taken at 8:03 AM on 8/9/94. Batteries 12, 5, and 10 were then discharge tested as described later in this report. Stabilized specific gravity readings were taken 4 days later at 5:40 PM on 8/13/94.

To perform the charge test the batteries were wired in series from number 1, being on the positive side of the charger, to number 12, being on the negative side of the charger. A City-el charger shunt was wired between the number 12 battery and the charger. This was used to measure the current output of the charger. A voltmeter was placed across the charger output wires, and a Hydria KWH meter was put on the AC input line to the charger. A schematic of the arrangement is provided as Figure 1 in the appendix. Descriptions of the equipment used for the test are given below.

Test Equipment.

Equipment	Model	S/N
Charger	Solectria BC1000-NEW	1002
Multimeter	Fluke 21 Series II Multimeter	58570412
Voltmeter	Sensitive Research Instrument Corp. Model C	942135
KWH meter	Hydria KWH Meter ST2400A	--
Shunt	City-el Charge Shunt 3.3 mV/A	--
Thermometer	SPER Scientific 76mm X 1mm Mercury	--
Watch	Casio Tri Graph 827 TGW-10	--
Hydrometer	Exide 62058BP-E (Failed before end of test)	--
Hydrometer	Plews 70-051 (Used for final SG check)	--

Data was taken using the following method. Specific gravity data was taken by randomly picking 4 to 5 cells of each battery. Where there was variation from cell to cell, the recorded SG was an eye ball average of the 4 to 5 readings from each cell. During the test, the Hydria W-h counter reading was taken the second it was time to record a data set. The Hydria power and line voltage readings were then taken followed by the pack voltage and the shunt mV reading. Each individual battery voltage was then measured. This process typically took 3 minutes. After this, the batteries were inspected for signs of gassing. This took about 4 more minutes. Temperature measurements were taken on a different battery for each data set except at the gassing point where temperature was taken on all batteries.

All of the raw data for the test was entered in the spreadsheet titled Solectria Force Charger and Battery Test 144V. This is Pacific EV file BATTTEST.XLS. See the appendix for a copy of this spreadsheet. The following list gives each column title and an explanation of the data contained in that column.

Title	Description
Date	Gives the date of the data.
Time	Gives the 24 hour time of the data.
Hours	Gives the elapsed hours of the charge test.
kilo Watts	Input power to the charger recorded from the Hydria KWH meter. In some cases this is an eyeball average. See Flux.
Watt-hr	AC energy use recorded from the Hydria KWH meter.
Line V	AC line voltage recorded from the Hydria KWH meter.
Flux	Indicates how stable the kilo Watts and Shunt mV readings were. Where a yes is indicated the recorded values for kilo Watts and Shunt mV are eyeball averages.
Pack V	Battery pack voltage as measured from the Sensitive Research Voltmeter.

Shunt mV	Milivolt reading across the City-el Charge shunt as measured by the Fluke multimeter. In some cases this is an eyeball average. See Flux.
Amps	Computes the output current of the charger using the formula: (Shunt mV)/3.3. This is based on the City-el charge shunt value of 3.3 mV/A.
Temp C	Degrees Celsius for the battery measured during each data set. This was taken using a partial submersion thermometer sitting on the battery post. The readings seemed to be the same as the ambient temperature though there is no proof of this.
Gassing?	Indicates whether there are visual signs of gassing in the batteries.
Batt 1 to Batt 12	Voltage for each individual battery.
Sum of V	Is computed as the sum of all of the individual battery voltages from battery 1 through battery 12.
Difference	Computed using the formula: (Pack V) - (Sum of V). This indicates the accuracy of the individual battery voltage readings.
Avg. V	Is the computed average of all the battery voltages from battery 1 through battery 12.
Stdev. V	Is the standard deviation for each of the average voltages recorded in Avg. V.
Max Diff.	This gives the voltage difference between the highest and lowest batteries.
DC Power	Computed using the formula: [(Pack V)*(Amps)]/1000. The result is in kilo Watts.
Charge eff.	Computed using the formula: (DC Power)/(kilo Watts).
W-h used	This gives the Watt hours used since the last data point. It is computed using the formula: [(current Watt-hr reading)-(previous Watt-hr reading)]*0.9. The 0.9 is a correction factor for the Hydria KWH meter which reads 10% too high for the Watt hour counter.
Specific Gravity	All of the batteries are listed and the specific gravity readings for them. The specific gravity readings are eye ball averages of 4 to 5 battery cells.
% Charge	These rows compute an approximate percent charge based on the specific gravity reading. An SG of 1.3 is considered 100% and 1.1 is considered 0%. These values are only an approximation since the specific battery chemistry was not known. The formula used is: (SG - 1.1)/(1.3 - 1.1)

From the data described above, several graphs were generated. These graphs are described and discussed in the following list. Refer to the appendix for these charts.

Solectria 144V Charger Profile Chart

> This shows the battery pack voltage and current profiles during the charging process. The x axis is not a numerical scale. Each time is given an equal part of the scale similar to a bar chart. This is why there are two zeros. The first zero is before the charger was turned on, and the second zero is immediately after the charger was turned on. The graph clearly shows the rapid reduction in current that occurs when the charger hits the gassing point. This is possible with solid state chargers. However, the graph also shows a significant reduction in pack voltage at the same time. It takes about 2 hours for the charger to bring the batteries back up to their previous voltage. It may take less time to charge the batteries if the charger were to step down to the gassing current in several steps while maintaining the pack voltage. It is unknown what effect this might have on the voltage variation shown in the Voltage Variation of Batteries During Charge chart described below. Further tests with a modified charger would have to be performed in order to determine the effects.

Charger Output Power and Efficiency Chart

> The curves for the output power and efficiency (power out/ power in) of the Solectria charger are shown. Note that the efficiency is given as a decimal instead of a percent so that it fits on the kilowatt scale. It is interesting to note that the efficiency of the charger remains essentially constant over the entire power output range. Efficiency averages 93%. The fluctuations in the efficiency line might just be due to measurement errors or it might be due to temperature variations. Tests including temperature measurements of the charger would have to be done to confirm this.

Voltage Variation of Batteries During Charge Chart

> Each individual battery voltage is shown over the course of the charge period. The average battery voltage is also graphed. The two sets of data points at 0 hours represent before charging and beginning of charging conditions. Total variation in battery to battery voltage reached a maximum of 0.58 volts just before the charger shut off.

Percent Charge Variation Chart

> This chart estimates the amount of charge in each battery before charging, 13 hours after charging, and 4 days after charging. The chart is based on the specific gravity readings with 1.3 being 100% and 1.1 being 0%. This is obviously only a rough approximation that ignores specific battery

chemistry for the Trojan 27 TMH batteries. It also ignores changes due to temperature fluctuations. Furthermore, it ignores the fact that the SG readings are not particularly accurate. None the less, it provides some information. Of particular interest are the final charges of battery 5 and battery 12. Battery 5 has the least charge after 4 days. Keep in mind that this battery was discharge tested and subsequently charged for only 7 hours on the 12V charger. Battery 12 on the other hand was the least charged after 13 hours but is about average after 4 days. This battery was discharge tested and then charged for 9 hours on the 12V charger. The point here is that the voltage variation shown in the Voltage Variation of Batteries During Charge chart is adversely affecting the batteries. Battery 12 would probably have come up further during the initial charge if the charger had supplied it with the charge it needed.

Discharge Test Procedure

This portion of the test was begun at 4:45 PM on 8/9/94. Battery 12 was done first followed closely by battery 5. Battery 10 was not done until 8:15 AM on 8/10/94. Battery 12 was charged for 9 hours on a 12 volt charger starting on 8/9/94. This was followed by battery 5 which was charged for 7 hours starting on 8/10/94. Finally, battery 10 was charged on the 12 volt charger for 9 hours starting at 4:00 PM on 8/10/94. This entire process occurs between the After 13 hour SG check and the After 4 days SG check.

To discharge the batteries, they were wired to a Mini-el battery discharger. A City-el main shunt was wired between the negative side of the battery and the discharger. The Fluke multimeter was used the measure the milivolt reading across the shunt. Voltage was measured using the Sensitive Research voltmeter wired across the terminals of the battery. Temperature was taken using a partial submersion thermometer set on the battery post. See figure 2 in the appendix for a complete schematic of the test setup. The complete list of equipment used for this test is given below.

Test Equipment.

Equipment	Model	S/N
Discharger	Mini-el 12.90	9105-06
Multimeter	Fluke 21 Series II Multimeter	58570412
Voltmeter	Sensitive Research Instrument Corp. Model C	942135
Shunt	City-el Main Shunt 0.33 mV/A	--
Thermometer	SPER Scientific 76mm X 1mm Mercury	--
Watch	Casio Tri Graph 827 TGW-10	--

Data was taken by recording the time and the corresponding amp hour counter reading on the Mini-el discharger. This was followed by a reading of the milivolts on the Fluke and then the voltage on the Sensitive Research voltmeter. Finally, the temperature was recorded. This process took about 30 seconds.

Data from this test was entered into the section titled Discharge Tests of the spreadsheet titled Solectria Force Charger and Battery Test 144V. This is contained in Pacific EV file

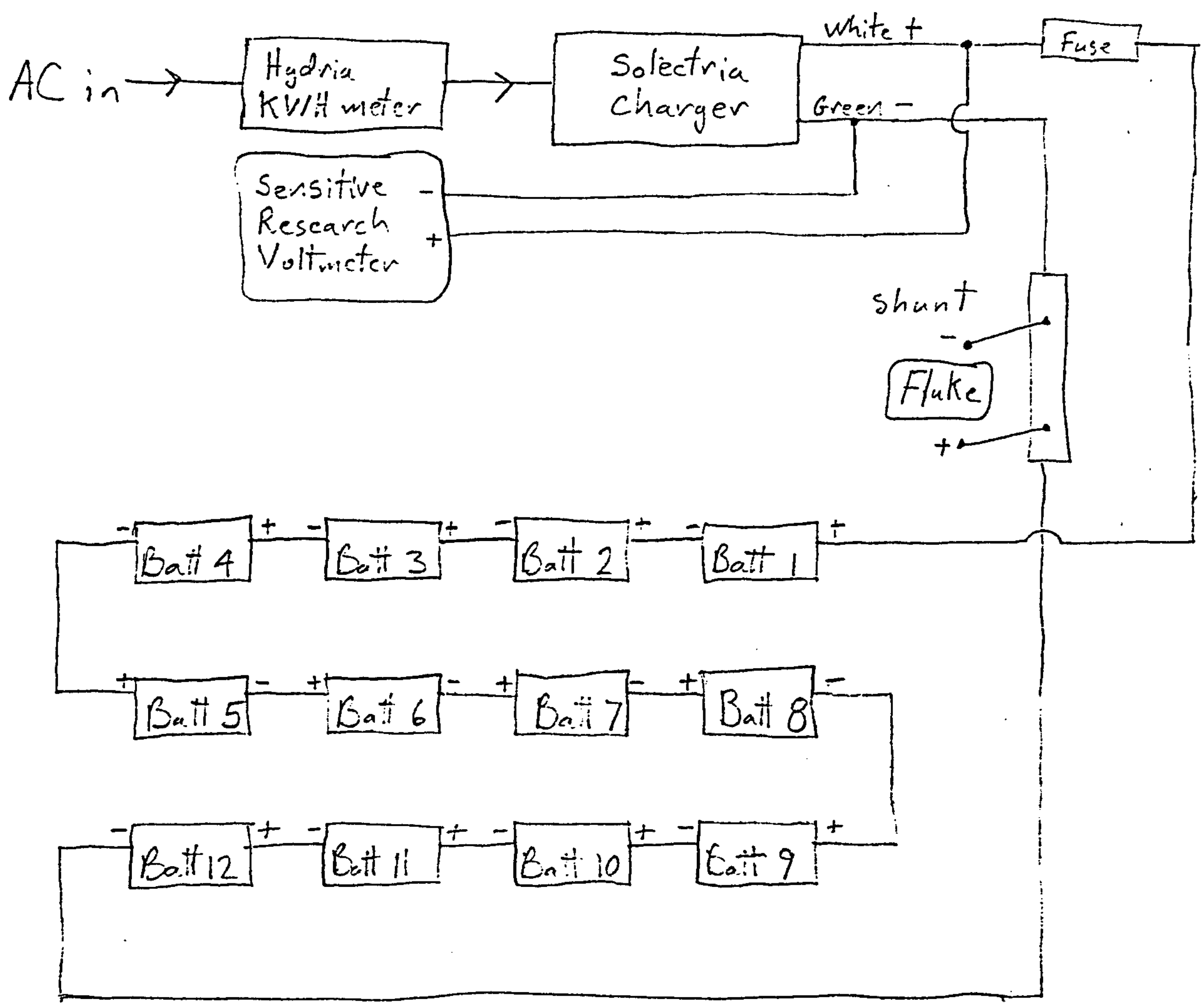
BATTTEST.XLS. Refer to the appendix for a copy of this spreadsheet. The following list gives each column title and an explanation of the data contained in that column.

Title	Description
Battery	Gives the number of the battery tested.
Date	Gives the date of the data.
Time	Gives the 24 hour time of the data.
Minutes	Gives the elapsed minutes of the discharge test.
Volts	This is the voltage of the battery.
mV fluke	The milivolt reading across the City-el main shunt as measured by the Fluke multimeter.
Amps	Computed from the formula: (mV fluke)/0.33 mV/A.
Amp hrs	Is the reading of the amp hour counter on the Mini-el discharger.
Post Temp (C)	The temperature of the battery as measured with the partial submersion thermometer set on the post of the battery.

From the data described above, the Discharge Test Battery Capacity in Amp Hours chart was generated. This graph shows battery capacity in amp hours for batteries 12, 5, and 10. Refer to the appendix for the chart.

APPENDIX

Test Setup



Fluke used across each battery for battery voltage.
Thermometer used on post of Batteries.

Figure 1. Schematic of Charge Test Setup.

Test Setup

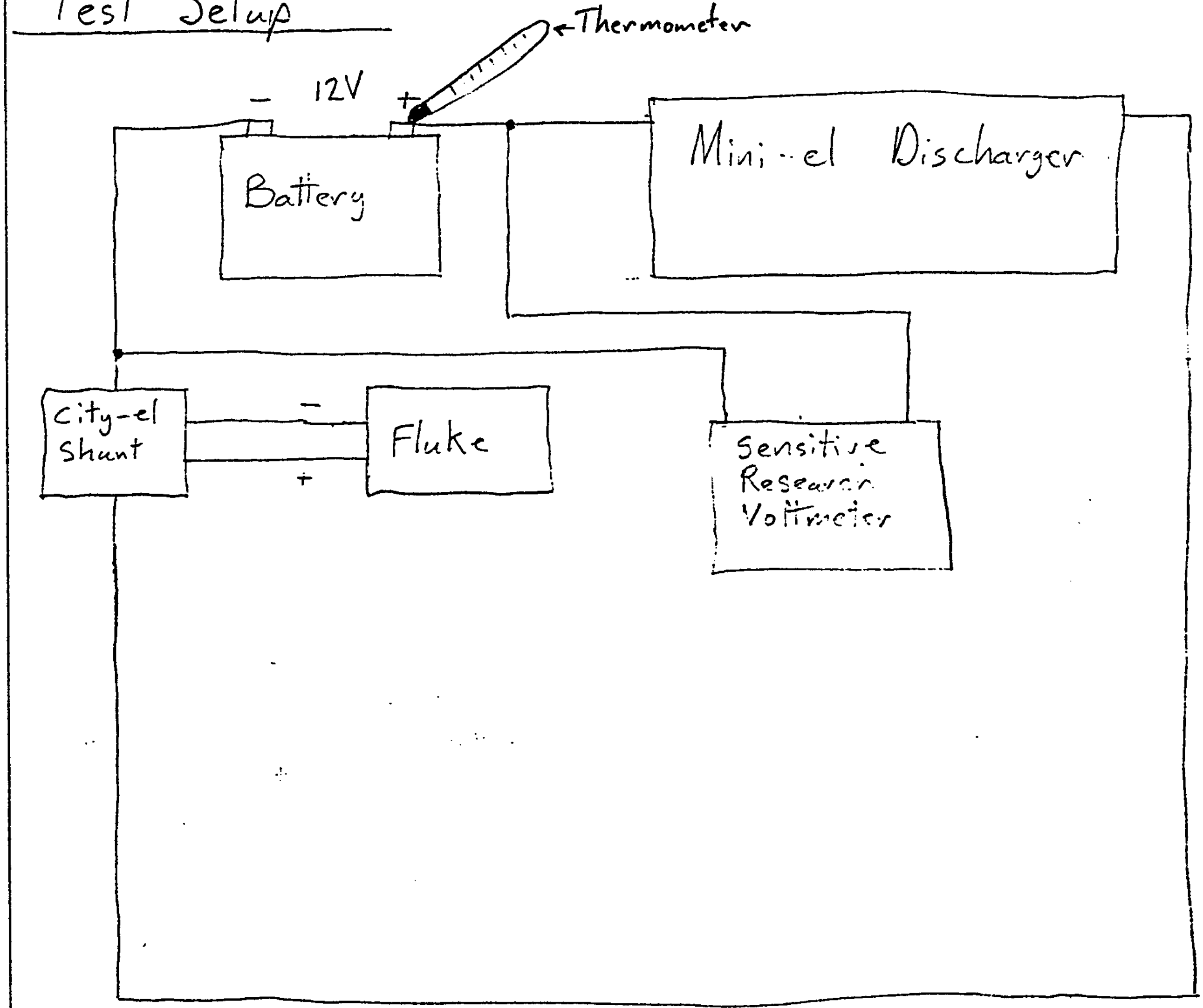


Figure 2. Schematic of Discharge Test Setup.

Solectria Force Charger and Battery Test 144V

Date	Time	Hours	kiloWatts	Flux	Watt-hr	Line V	Pack V	Shunt mV	Amps	Temp C	Gassing?	Battery Voltage Batt 1	Batt 2	Batt 3
8-8-94	8:45	0.00	0		2	0	150.2	0	0.00	25	no	12.45	12.53	12.49
8-8-94	9:32	0.00	1.15	yes	2	111	155	22.1	6.70		no	13.01	13.01	12.97
8-8-94	10:02	0.50	1.24	yes	743	112	158	23.2	7.03	24.5	no	13.19	13.17	13.15
8-8-94	10:32	1.00	1.28		1513	111	160	23	6.97	26	no	13.31	13.3	13.27
8-8-94	11:02	1.50	1.28		2283	112	162	22.5	6.82	26	no	13.45	13.44	13.4
8-8-94	11:32	2.00	1.22		3031	112	164.1	21.5	6.52	27	just barely	13.63	13.63	13.58
8-8-94	12:02	2.50	1.22		3648	114	167.5	21	6.36	28	slightly	13.91	13.91	13.85
8-8-94	12:18	2.77	1.17		4134	114	169.5	20	6.06	27.5	slightly	14.07	14.08	14.02
8-8-94	12:32	3.00	0.28	yes	4282	117	162	5	1.52	27.75	barely	13.49	13.48	13.44
8-8-94	13:02	3.50	0.26	yes	4446	115	163.5	5	1.52	28	barely	13.57	13.57	13.53
8-8-94	13:32	4.00	0.26	yes	4608	?	164	5	1.52	28	slightly	13.69	13.69	13.65
8-8-94	14:02	4.50	0.27	yes	4773	116	166	5	1.52	28		13.78	13.79	13.76
8-8-94	14:37	5.08	0.26	yes	4973	116	168	5	1.52		slightly	13.99	13.97	13.95
8-8-94	15:02	5.50	0.26	yes	5108	116	170	5	1.52	29	yes	14.14	14.18	14.16
8-8-94	15:32	6.00	0.28	yes	5279	117	172.5	5.1	1.55	29.5	yes	14.44	14.48	14.42
8-8-94	16:03	6.52	0.29	yes	5457	118	175	5.1	1.55	30	yes	14.72	14.71	14.69
8-8-94	16:32	7.00	0.29		5625	118	176.5	5	1.52	30	yes	14.93	14.9	14.86
8-8-94	17:02	7.50	0.29	yes	5801	118	178	5.1	1.55	30	yes	15.05	15.03	14.96
8-8-94	17:32	8.00	0.28		5973	113	179	5	1.52	30	yes	15.1	15.07	15.02
8-8-94	18:02	8.50	0.28		6155	119	179.5	5.1	1.55	31	yes	15.11	15.09	15.04
8-8-94	18:32	9.00	0.28		6333	118	180	5	1.52	31	yes	15.14	15.1	15.04
8-8-94	18:45	9.22	0.023		6414	120	167	0	0.00	31	no	13.8	13.79	13.75
8-9-94	8:03	17.52	0		6414	0	156	0	0.00	25	no	12.92	12.91	12.87
Discharge tests on Batt 5, 10, and 12. Batteries were then recharged.														
8-13-94	17:40	114.24	0		6414	0		0	0.00	29.5	no	12.82	12.8	12.76

Batt 4	Batt 5	Batt 6	Batt 7	Batt 8	Batt 9	Batt 10	Batt 11	Batt 12	Sum of V	Difference	Avg. V	Stdev. V	Max Diff.	DC Power
12.55	12.49	12.5	12.48	12.47	12.51	12.57	12.49	12.49	150.02	0.18	12.50	0.034	0.120	0.00
13.01	12.97	13.01	13.01	12.97	13.04	13.09	13.02	13	156.11	-1.11	13.01	0.033	0.120	1.04
13.19	13.15	13.17	13.17	13.14	13.21	13.25	13.18	13.17	158.14	-0.14	13.18	0.030	0.110	1.11
13.31	13.28	13.3	13.3	13.26	13.34	13.37	13.31	13.3	159.65	0.35	13.30	0.029	0.110	1.12
13.47	13.43	13.45	13.44	13.43	13.5	13.53	13.47	13.45	161.46	0.54	13.46	0.034	0.130	1.10
13.66	13.62	13.67	13.62	13.62	13.68	13.73	13.65	13.64	163.73	0.37	13.64	0.038	0.150	1.07
13.96	13.9	13.92	13.91	13.9	14	14.04	13.94	13.93	167.17	0.33	13.93	0.050	0.190	1.07
14.12	14.08	14.09	14.07	14.08	14.2	14.25	14.11	14.1	169.27	0.23	14.11	0.062	0.230	1.03
13.53	13.45	13.47	13.45	13.44	13.48	13.53	13.46	13.45	161.67	0.33	13.47	0.031	0.090	0.25
13.62	13.55	13.56	13.54	13.54	13.57	13.62	13.53	13.56	162.76	0.74	13.56	0.030	0.090	0.25
13.72	13.65	13.65	13.63	13.65	13.69	13.72	13.63	13.65	164.02	-0.02	13.67	0.032	0.090	0.25
13.85	13.76	13.75	13.74	13.78	13.83	13.84	13.74	13.76	165.38	0.62	13.78	0.039	0.110	0.25
14.04	13.95	13.95	13.9	13.94	14.05	14.07	13.9	13.93	167.64	0.36	13.97	0.057	0.170	0.25
14.24	14.13	14.09	14.04	14.1	14.27	14.28	14.03	14.07	169.73	0.27	14.14	0.085	0.250	0.26
14.42	14.35	14.35	14.21	14.25	14.48	14.55	14.21	14.26	172.42	0.08	14.37	0.115	0.340	0.27
14.6	14.51	14.5	14.34	14.4	14.69	14.8	14.37	14.41	174.74	0.26	14.56	0.159	0.460	0.27
14.73	14.62	14.63	14.46	14.48	14.86	15	14.5	14.49	176.46	0.04	14.71	0.199	0.540	0.27
14.82	14.74	14.73	14.53	14.53	14.98	15.1	14.57	14.58	177.62	0.38	14.80	0.217	0.570	0.28
14.87	14.8	14.79	14.59	14.59	15.08	15.16	14.64	14.63	178.34	0.66	14.86	0.218	0.570	0.27
14.91	14.82	14.85	14.67	14.63	15.1	15.2	14.71	14.66	178.79	0.71	14.90	0.204	0.570	0.28
14.94	14.85	14.88	14.66	14.63	15.11	15.21	14.74	14.67	178.97	1.03	14.91	0.206	0.580	0.27
13.79	13.71	13.69	13.68	13.66	13.67	13.72	13.63	13.64	164.53	2.47	13.71	0.060	0.170	0.00
12.99	12.9	12.92	12.9	12.93	12.9	12.96	12.89	12.91	155	1.00	12.92	0.032	0.120	0.00
														Average:
12.83	12.84	12.78	12.77	12.76	12.79	12.87	12.78	12.76	153.56	-153.56	12.80	0.036	0.110	0.00

Charge eff.	W-h used		Battery Specific Gravity Batt 1	Batt 2	Batt 3	Batt 4	Batt 5	Batt 6	Batt 7	Batt 8	Batt 9	Batt 10	Batt 11	Batt 12
	0.0		1.25	1.25	1.25	1.25	1.248	1.25	1.245	1.24	1.25	1.258	1.245	1.25
90%	0.0	% Charge	75.00%	75.00%	75.00%	75.00%	74.00%	75.00%	72.50%	70.00%	75.00%	79.00%	72.50%	75.00%
90%	666.9													
87%	693.0													
86%	693.0													
88%	673.2													
87%	555.3													
88%	437.4													
88%	133.2													
95%	147.6													
96%	145.8													
93%	148.5													
98%	180.0													
99%	121.5													
95%	153.9													
93%	160.2													
92%	151.2													
95%	158.4													
97%	154.8													
99%	163.8													
97%	160.2													
0%	72.9													
	0.0		1.3	1.29	1.285	1.29	1.285	1.29	1.29	1.28	1.285	1.3	1.275	1.255
93%		% Charge	100.00%	95.00%	92.50%	95.00%	92.50%	95.00%	95.00%	90.00%	92.50%	100.00%	87.50%	77.50%
	5772.6		1.295	1.295	1.28	1.29	1.27	1.275	1.275	1.275	1.28	1.285	1.28	1.275
		% Charge	97.50%	97.50%	90.00%	95.00%	85.00%	87.50%	87.50%	87.50%	90.00%	92.50%	90.00%	87.50%

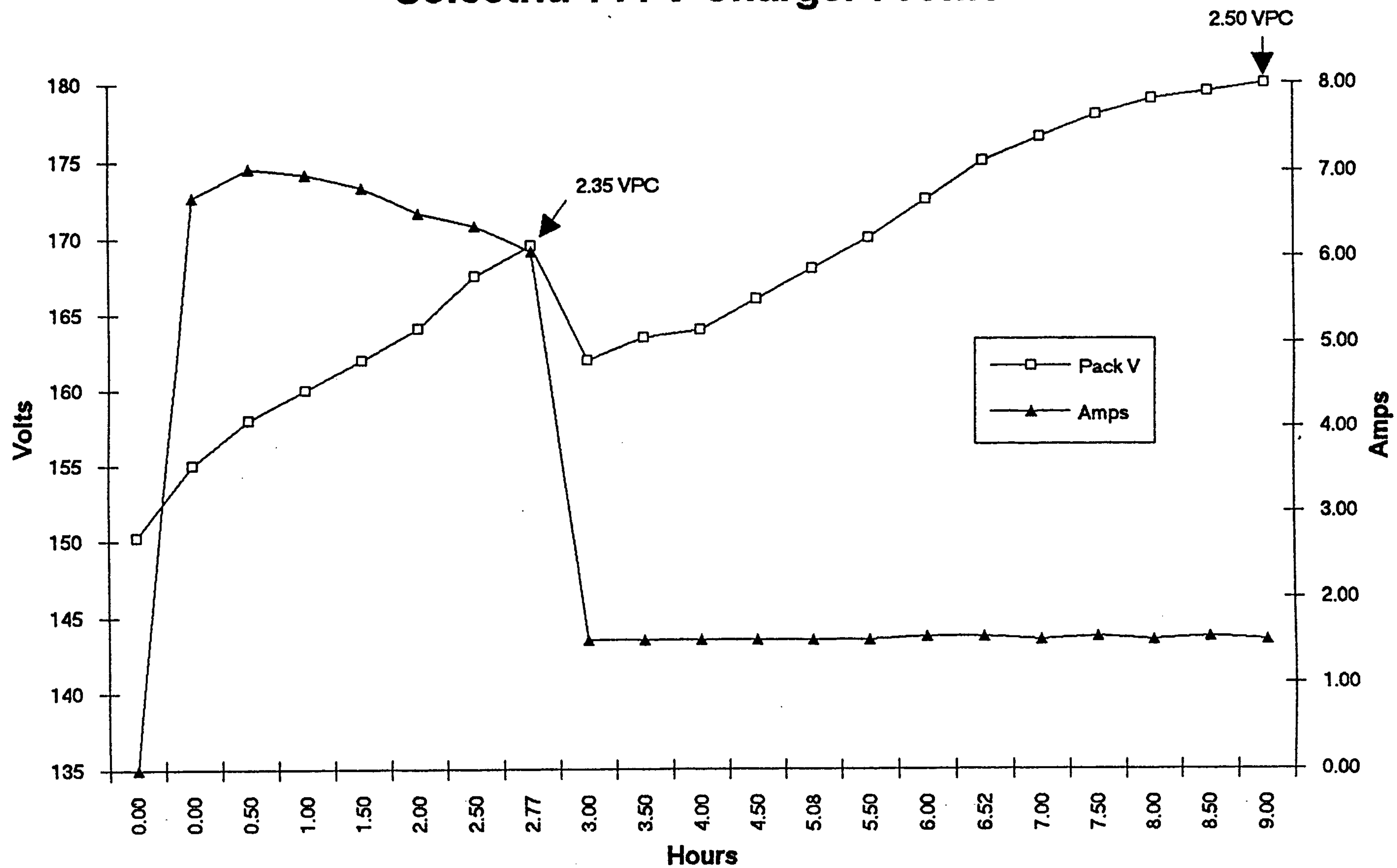
100% Charge SG 1.3 0% Charge SG 1.1

Discharge Tests

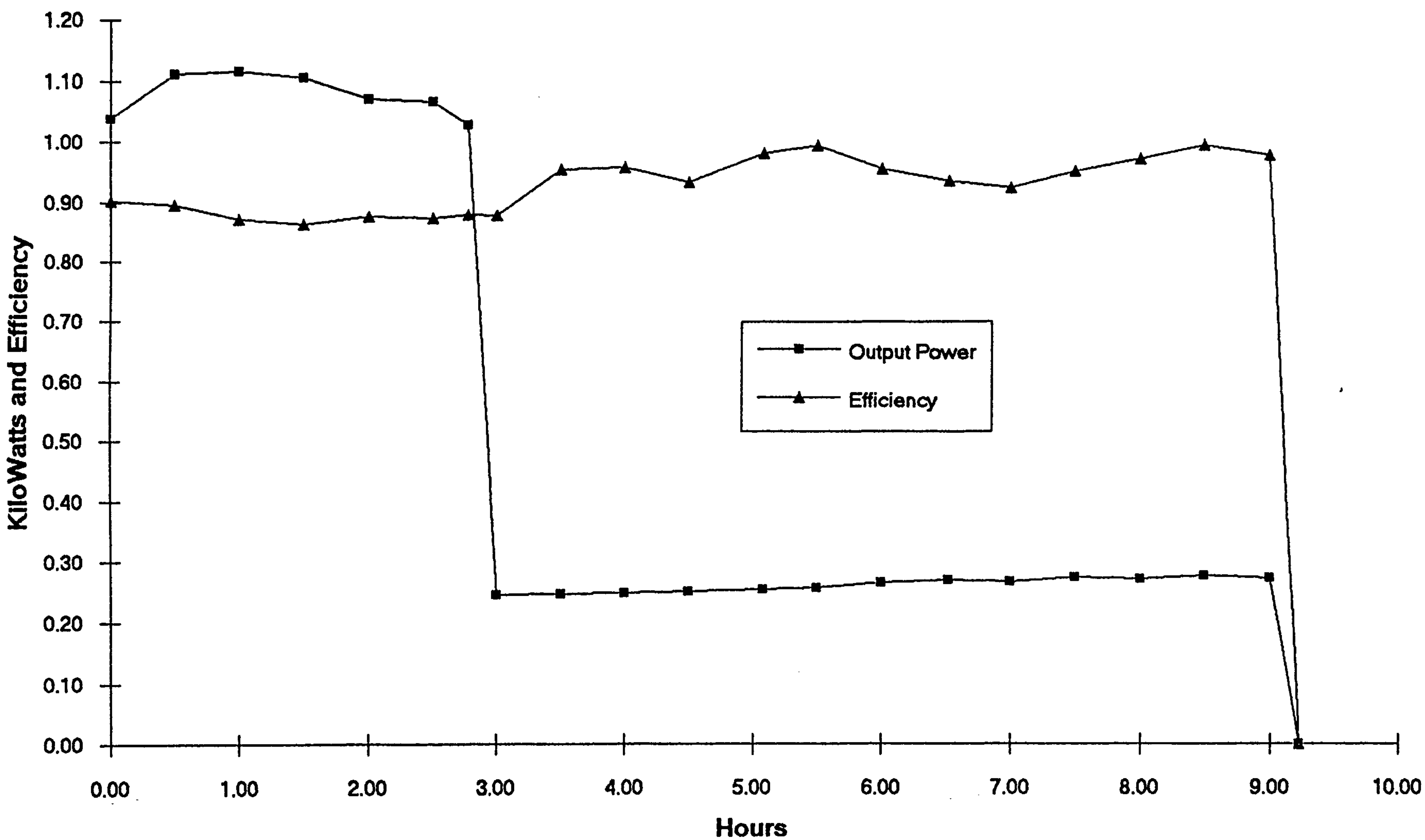
Battery	Date	Time	Minutes	Volts	mV fluke	Amps	Amp hrs	Post Temp (C)	
12	8-9-94	start	0	12.9	0	0.0	0	27	
	8-9-94	16:45	0	11.1	56.7	171.8	0	27	
	8-9-94	16:50	5	10.65	53.6	162.4	14	41	
	8-9-94	16:55	10		48	145.5	27	46	
	8-9-94	16:55:15				0.0			Shut off
	8-9-94	end		12.1	0	0.0	27.2		
5	8-9-94	start	0	12.9	0	0.0	0	28	
	8-9-94	17:15	0	11.1	58.1	176.1	0	28	
	8-9-94	17:20	5	10.75	54.4	164.8	14	40	
	8-9-94	17:25	10	10.05	51.2	155.2	27.3	46	
	8-9-94	17:27:55	12.92	9.4	48	145.5	32.2	46	Shut off
	8-9-94	end		12	0	0.0	32.2		
10	8-10-94	start	0	12.95	0	0.0	0	20	
	8-10-94	8:15	0	11.1	56.6	171.5	0	20	
	8-10-94	8:20	5	10.75	54.4	164.8	14	35	
	8-10-94	8:25	10	10.1	51.6	156.4	27.4	41.5	
	8-10-94	8:27:30	12.5	9.4	48.2	146.1	33.8	43	Shut off
	8-10-94	end		12	0	0.0	33.8		

Battery	Amp Hrs
12	27.2
5	32.2
10	33.8

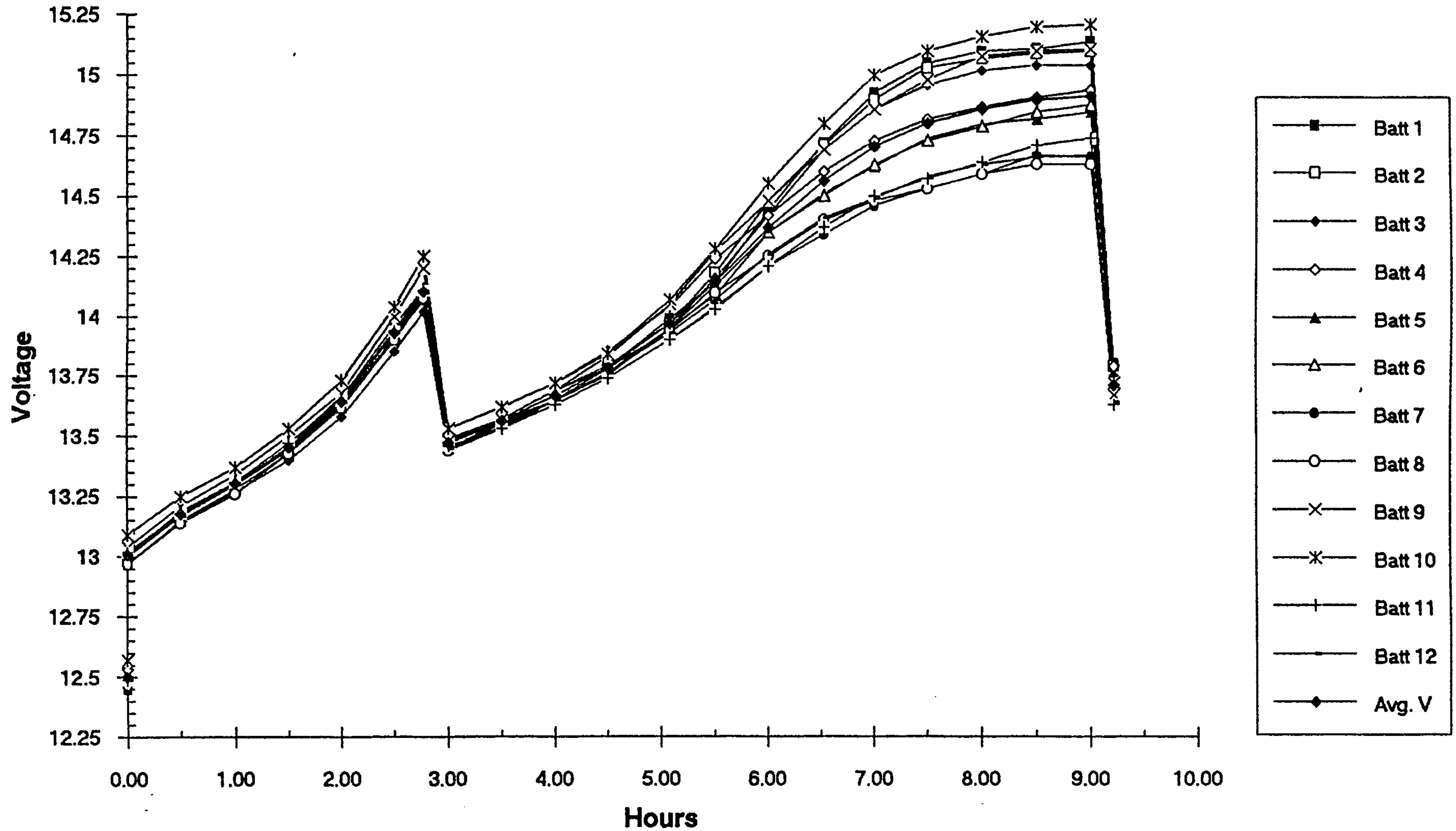
Solectria 144 V Charger Profile



Charger Output Power and Efficiency

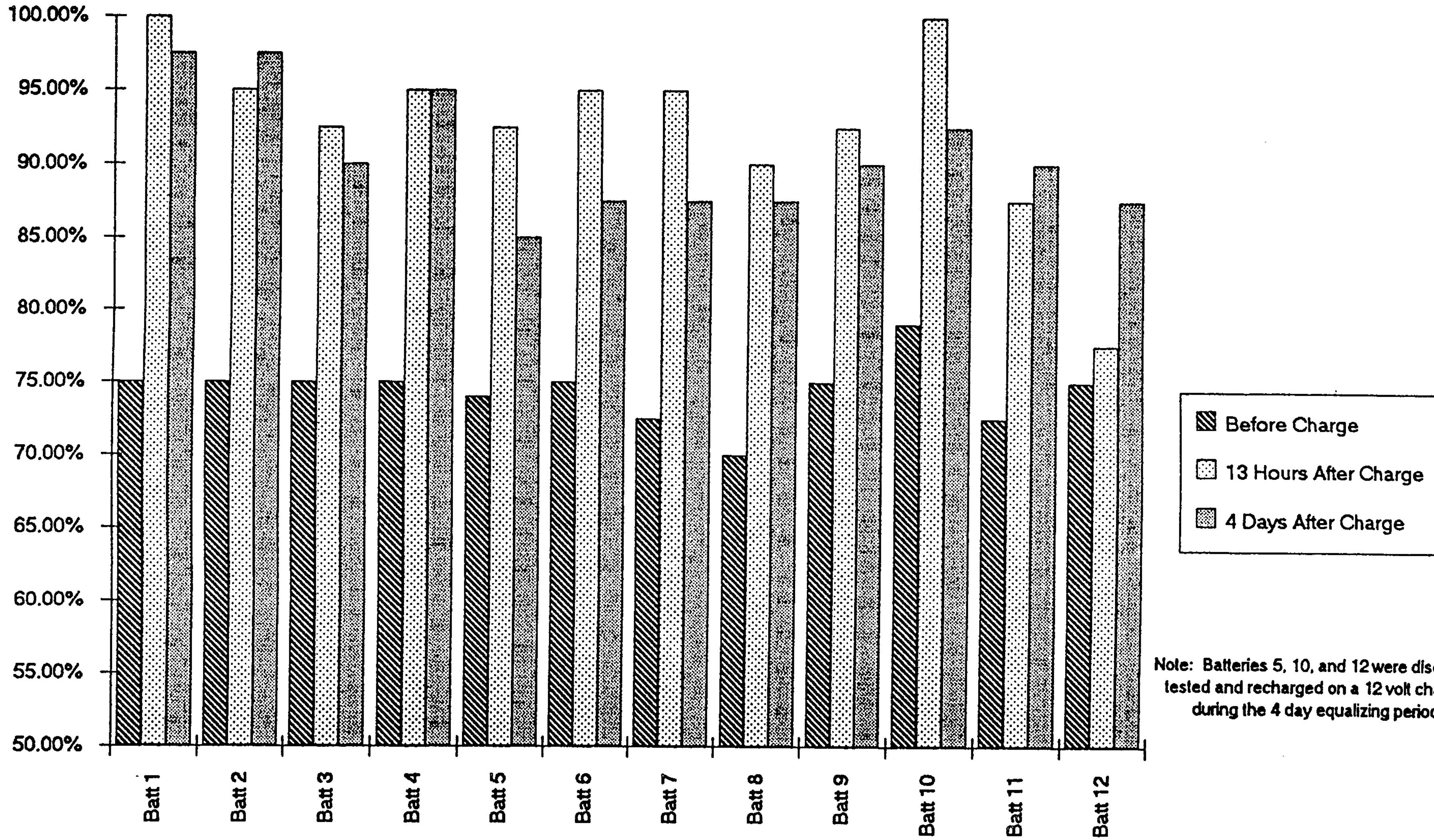


Voltage Variation of Batteries During Charge



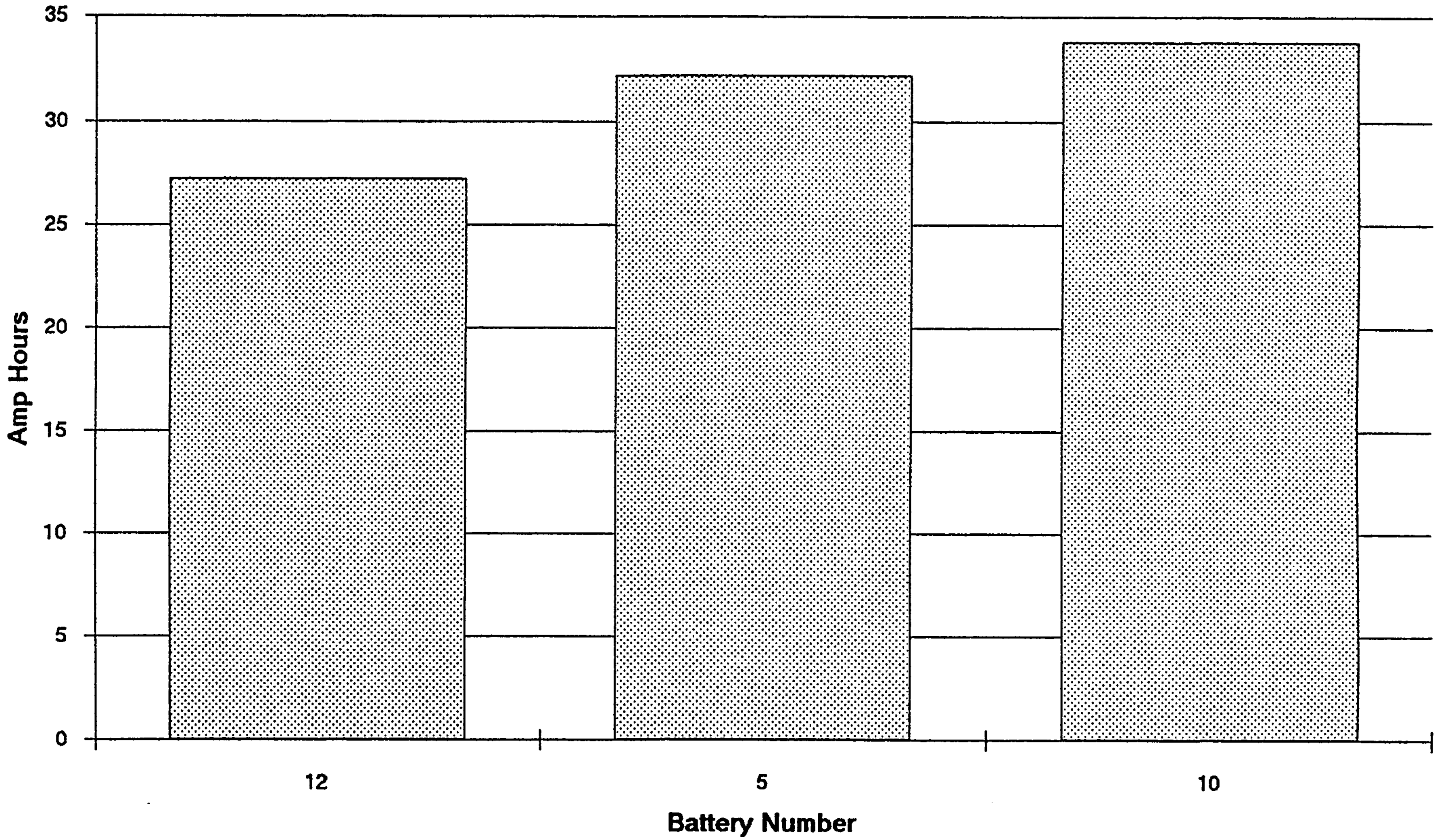
Percent Charge Variation

Note: The percent charge is only a rough approximation for the 25C to 30C temperature range. Since the specific battery chemistry was not known, 1.3 SG was selected as 100%, and 1.1 SG was selected as 0%.



Note: Batteries 5, 10, and 12 were discharge tested and recharged on a 12 volt charger during the 4 day equalizing period.

Discharge Test Battery Capacity in Amp Hours



Presentation Materials:

ARPA Electric and Hybrid Electric Vehicle Technology Program
Tri-Annual Program Review

9 - 11 May, 1994

Prepared by: William R. Warf PE
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Neighborhood Electric Vehicles, Product Development and Market Study

- Presentation Overview:
  - Project Overview
  - Present Status
  - Define Neighborhood EV (NEV)
  - Experience with the City-el
  - Advantages of NEV concept
  - Disadvantages of NEV concept
  - Project Goals
  - Schedule
  - Problems
  - Opportunities

Project Overview

- Market & Technical test with City-el
  - Long duration
  - Change in User's Opinions with time
  - Reliability, Life, actual energy use patterns
- Component Tests / Vehicle Improvements
- Glazing Study, ground vehicle canopy
- 4 Wheeled Purpose Built NEV For domestic manufacture (prototype construction)

Present Project Status

- 31 of 45 leased
- Dynamometer tests performed on three motors
- Two charger tests performed
- Market study in work
- Maintaining and taking data from deployed vehicles...
  - December to April...8500 miles... 5.5 MW-h
  - Now realizing about 2500 miles per month
  - About 250 W-h / mile best at plug
- Sourcing some parts in US as needed

Neighborhood EV: Definition

- Fit users needs for around town errands, short trips
- 35 miles per hour, 35 mile range
- 44 miles per hour top speed
- Low cost
- Low energy use, 100 - 150 W-h / mile at plug
- Existing technology & no special infrastructure

Experience With the City-el

- 31 of 48 vehicles leased, 25 to McClellan
- Customers using the City-el report meets their needs ... but suggest improvements:
  - Too small, doesn't feel safe, can other drivers see it?
  - needs more cargo room for facility use
  - needs 4 wheels plus two seats
  - rough ride
  - visibility out not adequate in wet weather
  - Uses too much energy (charger)
  - feels "flimsy...toy like"
  - Ingress-egress...get wet from drips
  - Too slow...for some uses

Attributes of the City-el

- Controls, instrumentation
- brakes good
- speed and acceleration adequate for closed facility, and for city street use for some customers
- uniqueness
- quiet
- demonstrated battery life of up to 300 cycles of 30 Amp hours DC Average
- Very low DC energy use

Advantages of NEV Concept

- Modest performance requirements
- Smaller battery pack...
  - fewer weak links (cells in series)
  - longer battery pack life
  - lower battery replacement cost
- Smaller Motor, less power required
- Charge any where without special plugs
- Lower Voltage may mean easier code compliance
- Pollution reductions more significant, since pollution is proportional to energy use
- Replace least efficient use of IC engine cars

Disadvantages of NEV Concept

- New Transportation Product, Education required as to which specific needs are met
- NEV needs to be small, and light, we will push personal space envelope
- FMVSS are tailored to larger cars
- Market acceptance will be slower, because of difference in concept
- Product must be in-expensive, price sensitivity is greater than a freeway capable EV

Product Development Goals

- Meet consumers needs for city (and town) errands
- Meet facility + closed campus user needs, errands, deliveries
- Focus on Chassis Design
- Develop system supplier partner: cost effective, efficient, programable charger
- Develop system, supplier partner, cost effective motor controller, high efficiency, with regenerative braking
- Prototype in 1994
- Pilot Production run in Late 1995

Engineering Goals

- < 400 kg curb weight
- 100 - 150 W-h / mile at plug
- Demonstrate > 300 cycle battery life
- 75 kg crash capable chassis (all thermoplastic + composite)
- efficient power delivery
- low un-sprung weight, with 10 year durability
- Cd*A < .45
- < 400 part numbers, highly producible
- Target Price: Low

Problems

- User acceptance... slower than we hoped, 31 of 48 leased ....(reduce price? decision, 6/1/94)
- Data acquisition ... behind schedule on installation ... add resources and complete by July 1, 1994
- Safety training may bias' market results

Opportunities

- Composite Wheels, 2 in. wide by 16-18 In. dia.
- Charger programable for different battery types
- Apply aircraft canopy technology to light vehicle...
  - Texstar
  - Sierracin Trans Tech
  - Pilkington Inc.
- Motor, Controller, Charger, capacity gage tests... do you have one we should test?

TEST REPORT:
CITY-EL CHARGER, TUNED FOR GNB EVB-1180 BATTERIES
10 JUNE, 1994

Prepared by: W.R. Warf, Pacific EV

Scope:
This test report provides the results of a test performed to confirm the City-el chargers which were modified under SMUD PO EV-50607 conform to the specifications provided. The modification of the charger boards was performed by Thun Electronic Engineering of Denmark, under Pacific EV Purchase Order 19. This report compares the test results to the specification requirements for each charge phase of a three phase curve. Data was recorded for both a brief "initial charge" plus a "full test charge".

Specifications:
The specifications for the charge algorithm were provided in a document titled "GNB; EVolyte 12-EVB-1180 Charging Recommendations" plus a letter from Joseph Szymborski of GNB to Jose Baer dated 5 April, 1994. The temperature compensation of the end of phase 1 "Gassing Voltage" was provided in the specifications included in the SMUD purchase order.

Results Summary: The chargers conform to the specification. Additional tests need to be performed once the batteries are "seasoned" by a number of discharge - charge cycles.

Test Set-up Summary:
The City-el is a 36 Volt system, and uses three batteries connected in series. Three EVB-1180's and a new charger board were installed in City-el VIN 4147 on June 1, 1994. The system uses the original charge transformer which provides 60 VAC power to the charger board. Initial battery pack voltage was 38 V. The charge transformer was plugged into the mains to confirm initial functioning, and then allowed to run through a charge cycle, which was short because the batteries were substantially fully charged. Gassing voltage and time for this "initial charge test" were recorded to provide a couple of additional points for confirmation of the specification. During this initial charge the battery temperature was 90 F.

The vehicle was then driven on June 2 to discharge the batteries under normal operating conditions. Approximately 1100 W-h (30 A-h) were removed from the batteries, as judged by the capacity gage indicating "3 dots left". Battery pack voltage was 37.5 volts at rest.

A volt meter was connected across the batteries, and a Fluke 21 used to measure voltage across the charger shunt (3.3 mV/Amp). The Hydria meter installed in the vehicle was used to measure AC power and time, and a mercury thermometer used to measure battery temperature at the negative terminal of the battery pack. Time was also measured using a watch, to confirm time readings of the Hydria. The charger was started, and data recorded manually at 15 minute intervals up to the gassing voltage at the end of phase 1; and at 5 minute intervals through phase 2, then at 15 minute intervals through phase 3. Data for the "full test charge" is provided in Figure 1.

Test Equipment:
1. Fluke 21 Series II Multimeter, S/N 58570412
2. Sensitive Research DC Voltmeter S/N 942135
3. Hydria KWh meter installed on transformer #114.
4. Mercury Thermometer

Test Results for Each Phase: The results of our tests are compared with the specification requirements in the following.

Phase 1, Constant Current:
Specification Requirement: Charge at an average current of about 12 Amps until the battery reaches 2.35-2.37 Volts per cell at 68 F. The end of phase 1 "gassing voltage" is temperature compensated according to the equation:

$V = 18 * (2.37 + (68-T) * .003)$ or, 3.0 to 3.1 mV/ degree F per cell

Where T is the temperature in degrees Fahrenheit as measured at the batteries.

Test results:
During the "initial charge" Phase 1 lasted about 4 minutes, since the batteries were at nearly full charge. The battery temperature was 90 F, which gives a gassing voltage of 41.5 Volts according to the specification. Battery voltage raised from 38 V to 41.5 volts during this 4 minute period at a current of about 10 Amps, and then the current began to drop while the Voltage was constant. The charger is therefore correctly compensating for temperature at the end of phase 1.

During the "full charge test" Phase 1 lasted 2 hours 45 minutes. Battery temperature was initially 78 F, and raised to 80 F during Phase 1. The end of Phase 1 gassing voltage according to specification is 42 V. At the end of phase 1 the voltage was in fact 42 V. Average current through phase 1 was 10.16 Amps. This is below the 12 Amp average provided by the specification, but is a power limitation of the existing charger, and is satisfactory. This average current delivered will probably change as the batteries are cycled, and may reach 12 Amps with seasoned batteries.

GNBCHGTS.XLS

FIGURE 1

CALCULATED

Temp. F	Notes	Time	DC Current	DC Volts	Time	DC Watts	AC Watts	Efficiency	Gas V	Phase Time	
78	Start	0	10.85	38.00	0:00	412.2424	600	69%	42.12		
78		0:15	10.61	39.00	0:15	413.6364	610	68%	42.12		Total
78		0:30	10.79	39.25	0:30	423.4242	630	67%	42.12		
78		0:45	10.61	39.50	0:45	418.9394	620	68%	42.12		
78		1:00	10.36	39.60	1:00	410.4	620	66%	42.12		
78		1:15	10.06	39.90	1:15	401.4182	620	65%	42.12	Phase 1:	
79		1:30	10.06	40.00	1:30	402.4242	610	66%	42.07	2:45	
79		1:45	10.06	40.40	1:45	406.4485	620	66%	42.07		
79		2:00	10.15	40.60	2:00	412.1515	630	65%	42.07		
80		2:15	9.94	41.00	2:15	407.5152	630	65%	42.01		
80		2:30	9.73	41.50	2:30	403.6818	630	64%	42.01		
80	Gas V	2:45	8.70	42.00	2:45	365.2727	560	65%	42.01		
80		2:50	8.06	42.00	2:50	338.5455	590	57%	42.01		
80		2:55	7.48	42.00	2:55	314.3636	500	63%	42.01		
80		3:00	6.85	42.00	3:00	287.6364	460	63%	42.01		
80		3:05	6.39	42.00	3:05	268.5455	430	62%	42.01		
80		3:10	5.94	42.00	3:10	249.4545	420	59%	42.01		
80		3:15	5.52	42.00	3:15	231.6364	390	59%	42.01		
80		3:22	5.00	42.00	3:22	210	370	57%	42.01		
80		3:25	4.85	42.00	3:25	203.6364	360	57%	42.01		
80		3:30	4.48	42.00	3:30	188.3636	330	57%	42.01		
80		3:35	4.18	42.00	3:35	175.6364	310	57%	42.01	Phase 2:	
80		3:41	3.82	42.00	3:41	160.3636	290	55%	42.01	1:35	
80		3:45	3.55	42.00	3:45	148.9091	280	53%	42.01		
80		3:50	3.30	42.00	3:50	138.7273	260	53%	42.01		
80		3:55	3.00	42.00	3:55	126	250	50%	42.01		
80		4:00	2.76	42.00	4:00	115.8182	237	49%	42.01		
80		4:15	2.15	42.00	4:15	90.36364	202	45%	42.01		
80		4:20	2.03	42.00	4:20	85.27273	191	45%	42.01		
80		4:25	1.88	42.10	4:25	79.09697	183	43%	42.01		
80	82%	4:28	1.85	42.10	4:28	77.82121	174	45%	42.01		
80		4:30	1.82	42.10	4:30	76.54545	173	44%	42.01		
80		4:35	1.82	42.50	4:35	77.27273	175	44%	42.01		
80		4:40	1.85	42.75	4:40	79.02273	174	45%	42.01		
80		4:45	1.85	42.00	4:45	77.63636	178	44%	42.01		
80		5:03	1.85	45.00	5:03	83.18182	161	52%	42.01	Phase 3:	
80		5:15	1.82	45.00	5:15	81.81818	162	51%	42.01	1:10	
80		5:20	1.82	45.00	5:20	81.81818	161	51%	42.01		
80		5:25	1.79	45.10	5:25	80.63333	153	53%	42.01		
80		5:30	1.79	45.25	5:30	80.90152	152	53%	42.01		
80	100%	5:34	-0.03	43.00	5:34	-1.30303	17				
80		5:40	-0.03	40.10	5:40	-1.21515	17				
80		5:46	-0.03	40.00	5:46	-1.21212	18		Phase 3 = (phase 1 + phase 2)/4		
80		5:50	-0.03	39.50	5:50	-1.19697	18		=	1:05	
									1/3 phase 1=	0:55	

Thermometer ON(−) terminal

WATCH

A

V

V * A

Hydria

DC Voltmeter

calculated from mV FLUKE

Phase 2, Constant Voltage:
Specification Requirement: Charge at the constant voltage reached at the end of phase 1, until the current drops to 2 amps.

Test Results:
During the "full charge test" Phase 2 lasted 1 hour 35 minutes, while the current tapered from 8 Amps to 1.88 Amps. At this point the 82% light on the City-el diagnosis box came on, and the voltage began to rise, indicating the end of phase 2. The battery voltage was constant throughout Phase 2 at 42.0 Volts. 1.88 Amps is 94% of the specification requirement, and is acceptable. It is noted that the actual end point current will probably vary some as the batteries age.

Phase 3, Constant Current
Specification Requirement: Continue charging at a constant current of 2 Amps to finish. During this phase the battery voltage will raise to about 2.5 VPC, or 45 volts. The time for Phase 3 is approximately 1 minute for every 3 minutes in Phase 1. At the end of Phase 3 the charger turns itself off.

Discussion: The counters used in the City-el charger do not allow division of the time in Phase 1 by 3. It was agreed during the modification of the chargers to divide the sum of Phase 1 plus Phase 2 by 4, since this is within the capability of the counters, and provides a good approximation of the specification requirement.

Test Results:
During Phase 3 the average current for the "full charge test" was about 1.83 Amps. This is 91 % of the specification requirements, and is acceptable. The voltage did in fact raise to 45.25 volts. The length of Phase 3 was 70 minutes, and the charger turned itself off. Review of the data in figure 1 shows that a small discharge of about 30 mA begins at the end of phase 3, indicating the charging had ceased. One third of the time for Phase 1 would give a time of 55 minutes, and one fourth of the time for Phase 1 + Phase 2 gives 65 minutes. Therefore the charger conforms reasonably with the specification requirement for Phase 3, as the current is slightly low and the time is a little longer than specification.

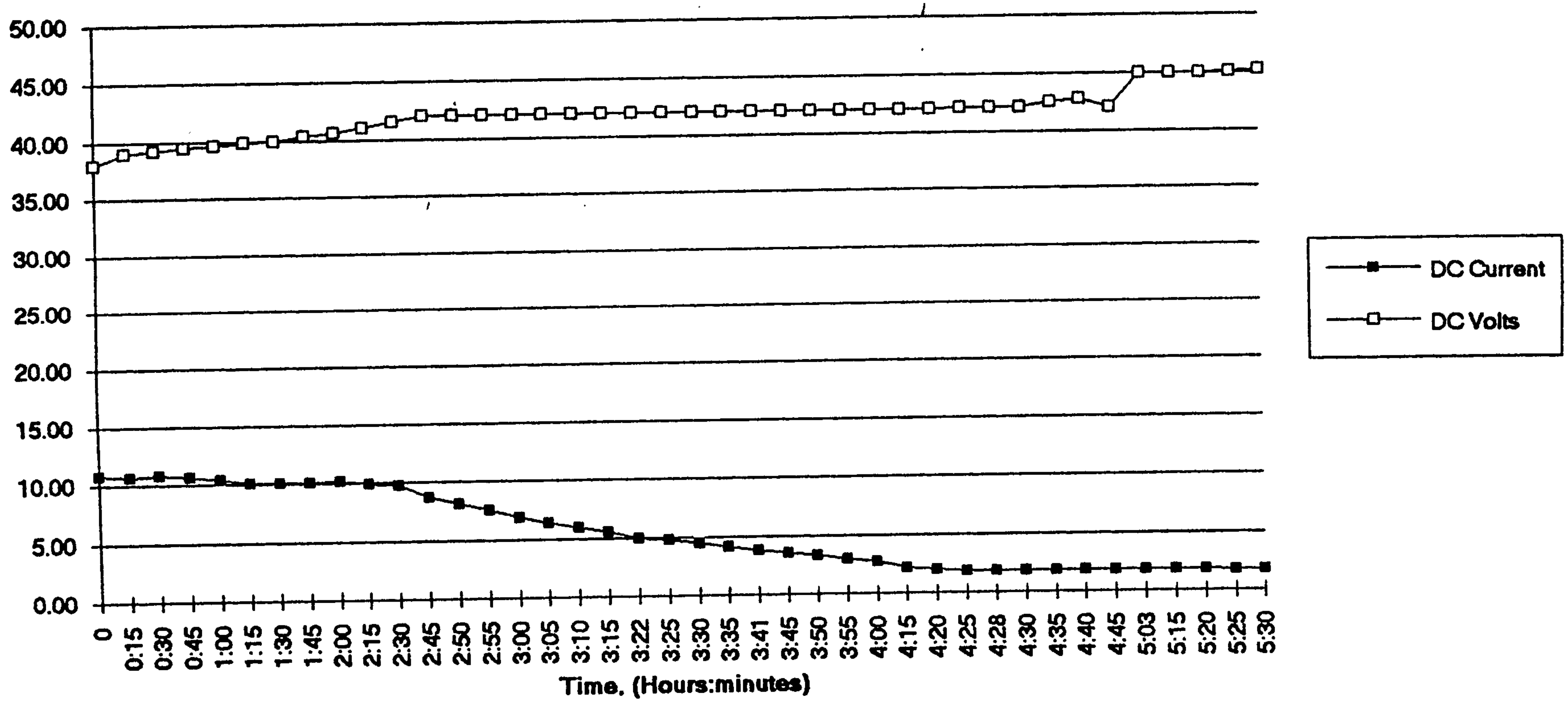
During the "initial charge test", the time for Phase 1 was about 4 minutes, the time for Phase 2 was 144 minutes, and the time for Phase 3 was 30 minutes. This is within the agreed 1/4 of phase 1 plus phase 2 time. This may present more time in Phase 3 for the batteries than intended by the manufacturer, since vehicles which are not driven daily discharge themselves due to the 20-30 mA draw from the capacity gage. In some cases, these vehicles will be plugged in after sitting unused for a few days, and will receive a short phase 1 plus a normal phase 2 plus phase 3

charge, which may be similar to the initial charge test we performed. It will be very beneficial to complete installation of data acquisition systems such that the number of these cycles is recorded.

Graphs: Graphs of the data provided in Figure 1 are attached for Voltage and Current versus time and AC power and DC power versus time. Figure 2 provides the Energy withdrawn from the plug, and delivered to the batteries in tabular form.

Conclusion:
The modified charger conforms to the specification. Additional tests need to be performed once the batteries have about 30 charge discharge cycles on them, to verify again conformance to specification.

City-el Charger, GNB EVB-1180 Batteries



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AC Watts at plug vs DC Watts at Battery

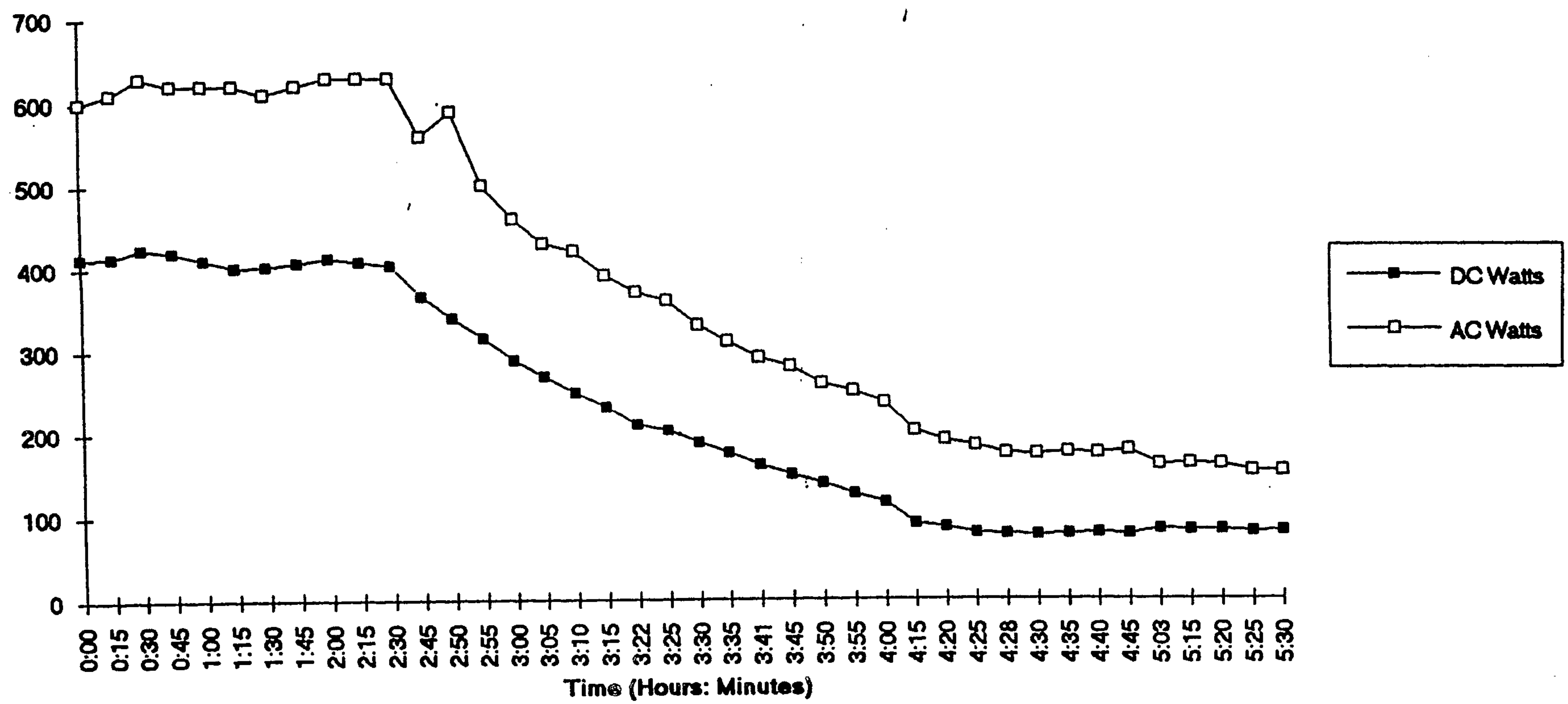

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FIGURE 2

GNBCHGTS.XLS

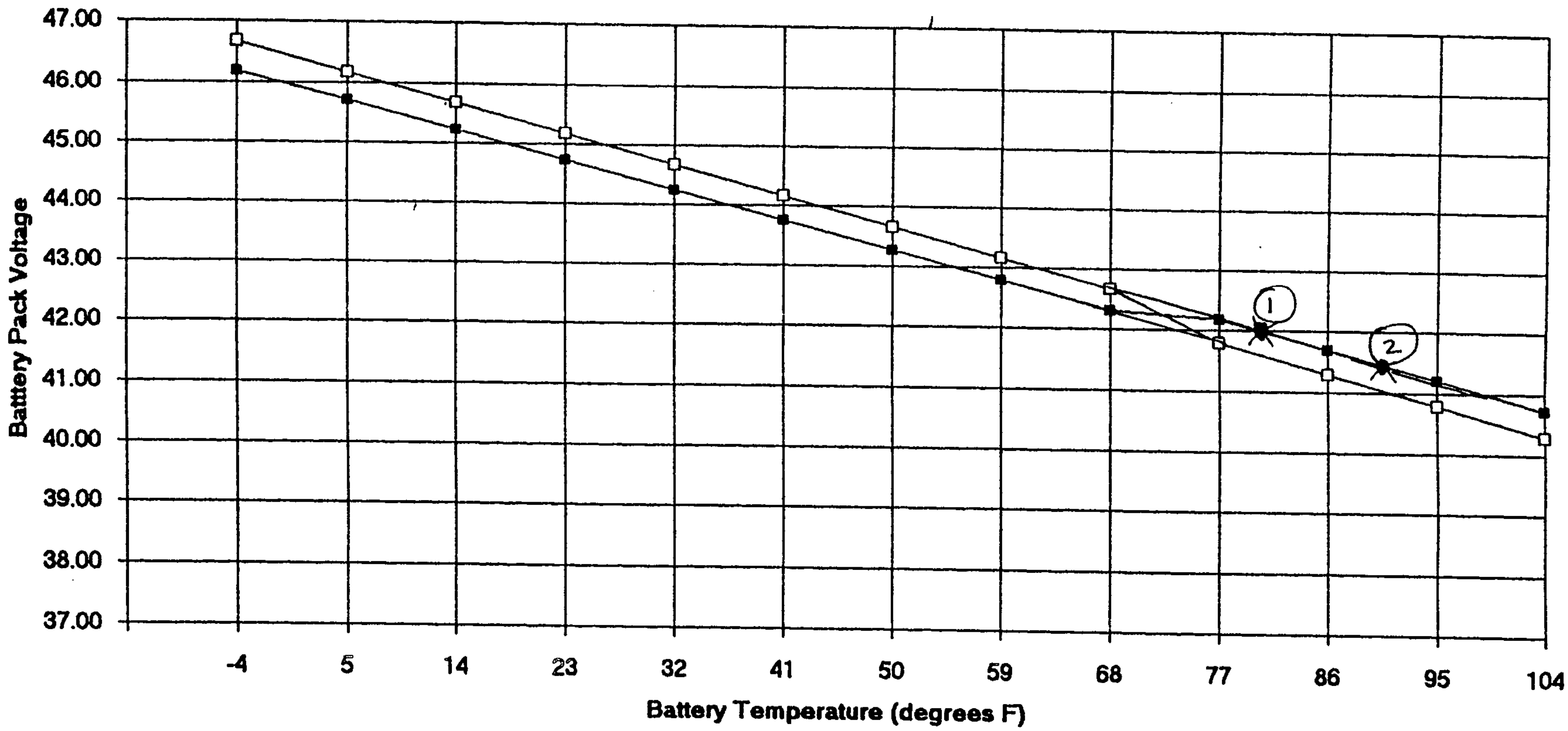
DC W-h	AC W-h	Time
0	0	0:00
103	162	0:15
209	333	0:30
314	504	0:45
417	675	1:00
517	846	1:15
473	1017	1:30
721	1179	1:45
824	1350	2:00
926	1521	2:15
1026	1692	2:30
1121	1863	2:45
1145	1908	2:50
1170	1953	2:55
1196	2007	3:00
1218	2043	3:05
1238	2079	3:10
1258	2115	3:15
1282	2169	3:22
1292	2187	3:25
1309	2214	3:30
1323	2241	3:35
1339	2277	3:41
1349	2304	3:45
1360	2322	3:50
1372	2349	3:55
1381	2376	4:00
1403	2430	4:15
1409	2448	4:20
1417	2466	4:25
1421	2475	4:28
1424	2475	4:30
1430	2493	4:35
1437	2511	4:40
1443	2529	4:45
1468	2583	5:03
1485	2619	5:15
1491	2628	5:20
1497	2646	5:25
1505	2664	5:30

PHASE 1 (0:00–2:45)

PHASE 2 (2:50–4:20)

PHASE 3 (4:25–5:30)

Temperature compensation Specification for GNB EVB-1180



POINTS CONFIRMED

X 1 FULL CHARGE TEST 80°F

X 2 INITIAL TEST 90°F

6/11/94

9

[signature] 6/11/94

NEIGHBORHOOD ELECTRIC VEHICLE WORKSHOP, PRESENTATION SUMMARY

June 30, 1994

Prepared by: William R. Warf
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

PRESENTATION SUMMARY:
NEIGHBORHOOD ELECTRIC VEHICLE WORKSHOP,
June 30, 1994 presented by William R. Warf, Pacific EV

Abstract:
Pacific Electric Vehicles is working with SMUD to study the market potential and technical merit of Neighborhood Electric Vehicles (NEV's). The study involves the leasing of 48 City-el electric vehicles which were manufactured in Denmark and acquired for the program. Utilizing the information gained from the market and technical study, an NEV prototype is being developed for the US market.

This presentation will overview the scope of our project including what we have learned so far about the market place and the technology. A summary of the product specification for our prototype EV is presented, and the pollution reduction benefits of NEV's relative to other electric vehicles is discussed.

Program Overview:
SMUD has a large EV fleet consisting of 38 vehicles in addition to our 48 City-el's. This fleet is composed of 14 City-el's, 2 Trans 2's, 2 Horlacher prototypes, 11 conversion pick-up's, 4 passenger car conversions, 3 Conceptor G-Vans, and 2 Electric busses. The SMUD EV program includes study of a flywheel battery system, freeway capable low mass vehicles, station cars, and neighborhood EV's.

Our part of the program is to manage the NEV project and to acquire technical and marketing data through leasing of the City-els. We are testing components, studying light weight glazing, and constructing an NEV prototype. So far we have leased 34 of the 48 vehicles at $120 per month. Tests of advanced batteries and US made components are ongoing. To date we have realized about 12,000 City-el miles, and have used about 8 M-W hours of electricity measured at the plug. All lease customers receive mandatory training in safe City-el use, which provides an operator's orientation to the vehicle systems and a strong warning regarding the cornering limitations of the vehicle.

Based on our studies to date, we define an NEV as a vehicle which meets consumer's needs for short trips or errands which do not require freeway travel. An NEV has a 35 mile range at 35 mph, a top speed of 44 mph, low cost and low energy use. NEV's utilize existing infrastructure, because of low power requirements.

Market Study Results:
Is there a market for such a vehicle? All the market studies say yes, if the right combination of utility, comfort, and cost is achieved. This conclusion is based on market study results from our own customer interviews, ITS studies, DeVry Institute of Technology Studies, and surveys of McClellan Air Force Base personnel using the City-el performed by California State University, Sacramento. Some of these survey results are summarized in the following.

In studies of individuals in Atlanta and South Florida performed by Sandra McKee of DeVry, 31 % of respondents surveyed indicated the most troublesome part of car use is stopping to refuel with gasoline. Most respondents in this survey drive 30-50 miles per hour, and can accomplish their transportation needs without using the freeway. All respondents say cars are too expensive.

Joe Orsini of Sacramento State University performed interviews of City-el operators at McClellan AFB. The interviews were performed upon introduction to the vehicle, and at 6 and 12 weeks after introduction. These respondents indicated that the vehicle's range and speed were acceptable on Base. They liked the accessories, quiet operation, and ease of parking. It is interesting to note they mentioned the air quality benefit of the vehicle only in the first interviews.

Regarding concerns about the City-el, the Air Force Base users express dissatisfaction with the ride and handling. Because of vehicle size and "flimsy construction" these interviewees expressed strong concerns regarding using the City-el off of the Air Force Base. It seems likely that our warnings regarding the handling properties of the vehicle have made an impact, and may have influenced our study results.

We have talked to many people regarding the City-el. They have said that if we had a vehicle with four wheels and two seats they would buy one. The main dislikes of the City-el are the three wheeled design, poor ride and handling, slightly too slow, one seat, and that the price ($8000) is too high.

These Market Survey results suggest to us that a well developed vehicle which has roughly the same capabilities and finish as the City-el, in which people can feel safe and go a little faster is sale-able in sufficient numbers to warrant tooling for limited production. The first step is to develop a prototype with the attributes of the City-el, with more utility, comfort and convenience than a City-el.

Technical Study Results:
Compared to other EV's, Neighborhood vehicles have more modest performance requirements because there is no need for higher freeway speeds. A lower power

drive, charger, and a significantly smaller battery pack can be used, all of which will contribute to lower production and life cycle costs. NEV's will operate at lower voltage, which may mean easier compliance with electric codes, and which greatly simplifies the charging system.

NEV's have disadvantages also. These limited use transportation products will not be accepted quickly unless the price is low. An NEV must be small and light, at the lower bounds of the "personal space envelope", which is the volume inside the vehicle which allows passengers to feel comfortable. In addition, the Federal Motor Vehicle Safety Standards are based on larger cars, and a production NEV has to satisfy the current standards.

Review of all available measured data regarding the energy use of EV's confirms that energy use is a strong function of vehicle mass. NEV's can be expected to use energy between 80 and 300 W-h/mile depending on the systems employed in the vehicle. Conventional, heavy vehicles, including EV conversions, will use between 300 and 1200 W-h per mile. View graphs illustrating "at the plug" energy use from Solar Cup Denmark and from the SMUD fleet are provided in the attachment to illustrate this fact.

Advanced electronics and light weight allowed the Felix to use less energy, carry two people, and go almost as fast as up-rated City-el prototypes in Solar Cup Denmark.

It is worth noting that the City-el charger includes a holding charge during which the charger draws 40 W as long as it is plugged in. If the vehicle is unplugged, a small current draw will discharge the batteries over a span of 4-6 days, so it is usual for City-el users to leave the vehicle plugged in. The result of this design is that energy use in a City-el varies strongly with the amount of vehicle use. A chart was prepared from measured data which illustrates this fact. This explains the variation in City-el energy usage in Solar Cup versus the use seen at SMUD. In fact, SMUD drives their City-el's about a mile a day average, which probably means a couple of miles, every other day.

The City-el systems were dissected to examine the energy losses in various parts of the vehicle system. The rolling resistance was determined by roll down test, and a plot made for power required at the average measured coefficients of drag and rolling resistance. At the road, a City-el requires about 1.5 kW at 30 miles per hour, and 3.5 kW at 45 miles per hour. This results in energy usage in average trips of about 57 W-h per mile at the road, and about 190 W-h per mile at the plug, neglecting holding charge and "always on" losses. The systems diagram and the

pie chart provide a breakdown of the difference between at the plug and at the road energy use.

We have postulated a preliminary design specification and an energy budget for our prototype NEV "Picador". These are provided in the attached view graphs titled "Picador: Vehicle Dynamics", "Picador: Electrical Drive" and the pie chart titled "Picador NEV average energy use, Engineering goals, 140 W-h/mi at Plug".

Is pollution proportional to energy use?
A brief analysis was performed to quantify emissions from electric vehicles charged by fossil fuel generated energy, compared with internal combustion engines in vehicles. In order to make the comparison the emissions regulations were translated into the mass of allowable pollution per unit energy generated from both fixed and mobile sources. The analysis does not attempt to incorporate a thorough cost-benefit analysis, costs of refining the fuels, concentrations of pollutants, or the actual electric power generating mix. This is necessarily an overly simplistic approach, but the result suggests that allowable pollution is indeed a function of energy use, and therefore a function of vehicle mass. The assumptions used in the calculations are provided in the attached view graphs.

One surprise was that the regulations permit higher emissions per unit energy from a high mileage economy car than they would for a lower mileage car. This seems consistent with the economy car's lower market price, since simpler control technologies need to be applied to keep costs down. See GAS.XLS Chart 3, attached.

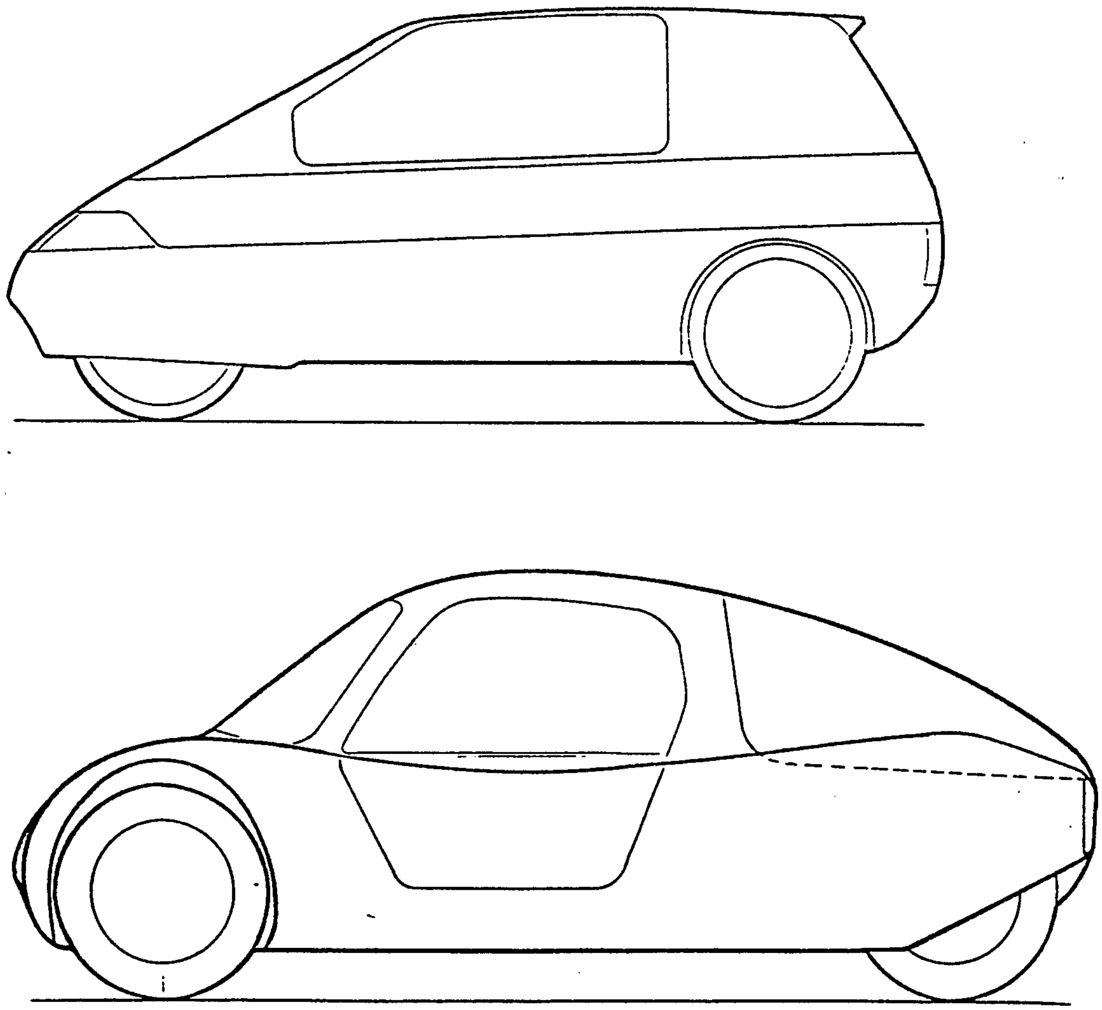
Given the assumptions used, the emissions from light weight EV's work out to between 0.3 and 0.7 grams per mile, while heavier electric vehicles emit between 1 and 3 grams per mile.

PV Recharging
I was surprised at the amount of energy lost in transmission from the power plant to the user. The longer the transmission distance, the larger the losses. This suggests further work is needed to develop recharging of vehicles using fixed photo-voltaic arrays, which might have essentially zero transmission losses. The problem is the cost of the arrays, and the space they take up.
Using the energy use data presented for the SMUD fleet, the area of a PV array required to fully recharge a vehicle in 6 hours after a 10 mile trip was estimated. NEV's are the most feasible to recharge using photovoltaics, since a smaller array is needed. My calculation shows that NEV's might be recharged by a 4 square meter array, while converted passenger vehicles will require 8 - 12 square meters, and pick-ups and G vans will require more than 20 square meters of array surface. The

results of my calculation are shown in the chart "energy use for 10 miles, PV array area for 6 hour recharge".

Summary:
Neighborhood EV's can provide greater benefits than other EV's in terms of reduced energy use, less pollution, and lower cost. Market study results are encouraging, in that consumers have identified a variety vehicle attributes which may be more important than range and speed. Consumers suggest that a vehicle similar to the City-el that offers more utility, more comfort, and a little more speed would be quite acceptable for much of their transportation needs.

The largest problem in NEV development is the ability of a small, light vehicle which provides adequate passenger safety, and fulfills the crash test standards provided in the Federal Motor Vehicle Safety Standards. It is noted that since an NEV is by definition slower than conventional automobiles, the overall safety of passengers is easier to achieve than it is in vehicles capable of higher speeds.



CONCEPT: NEV PROTOTYPE VS MINI-EL

PACIFIC EV
6/12/94

Neighborhood Electric Vehicle Workshop, presentation overview:

- SMUD's EV Program
- NEV Project Overview
- Market Studies
- Test Results and analysis
- New NEV prototype specification
- Pollution reduction benefits of NEV's
- Summary

SMUD EV Fleet

- 38 Vehicles
- Variety: Bus to City-el
- > 500,000 Miles
- SMUD Programs include:
- Flywheel system
- Freeway capable-station car
- Conventional Conversions, Vans, Cars, Trucks
- Neighborhood Vehicles: Trans 2 and City-el

NEV Project Overview

- Market & Technical test with City-el
  - Long duration
  - Change in User's Opinions with time
  - Reliability, Life, actual energy use patterns
- Component Tests / Vehicle Improvements
- Glazing Study, light weight vehicles
- 4 wheel, City-el based, chassis development buck
- Prototype 4 Wheeled Purpose Built NEV For domestic manufacture: "Picador"

NEV Project Status

- 34 of 45 leased,
- Some Component and System tests complete
- First Vehicle fitted with VRLA batteries
- DAS Installations in process
- Market studies On-going
- Maintaining and taking data from deployed vehicles...
  - December to May...11,635 miles... 8.1 MW-h
  - Now realizing about 2500 miles per month
  - About 250 W-h / mile best at plug

Neighborhood EV: Definition

- Fit users needs for around town errands, short trips
- 35 miles per hour, 35 mile range
- 44 miles per hour top speed
- Low cost
- Low energy use, 100 - 150 W-h / mile at plug
- Existing technology & no special infrastructure

Is there a Market?

- All market studies say yes if...
- Production cost is critical... but it is easier to build a reasonably priced NEV than a full size electric car...
- First some market study results:

DeVry: Sandra McKee Market Studies in South Florida and Atlanta

- "To our amazement 31% of individuals surveyed felt stopping to put in gas in the car was most bothersome part" (of car use)
- 70 % of respondents can accomplish there transportation needs without the freeway
- 60 % drive 30 - 50 mph most of the time
- 100 % say cars are too expensive

Orsini's McClellan City-el User Survey: Attributes

- Speed and Range acceptable on base, and for some public street uses
- Accessories acceptable to good
- Quiet Operation
- Parking is very easy
- Note the air quality benefit is mentioned at first, but over several months...no longer brought up.
- Also note, these users are driving the City-el for free!

Orsini's McClellan City-el User Survey: Concerns

- Safety Concerns ranged from a feeling of aprehension to fairly strong fear
- Suspension design resulting in a harsh bumpy ride is an annoyance, and a safety item.
- "It looks a little flimsy"
- "I don't think I would use it in the (off Air Force Base) real world."
- Helmets don't fit, making vehicle less suitable for "fleet" use.

Pacific EV's Market Study

- "If you had one with four wheels and two seats I'd buy one"
- "look, the car of the future"
- Main dislikes of Mini-el:
  - 3 wheels ... Helmet ... poor ride and handling
  - Too Small / Too Slow
  - One Seat
  - Price Too high!
- "It's like driving a bicycle in the lane for cars"

Summary of Market Surveys:

- People understand the benefits of a low energy use vehicle
- People mention safety first
- Utility, comfort, and convenience are minimums for a saleable NEV
- Range and speed of the City-el are acceptable values for most, a little higher speed capability is in order

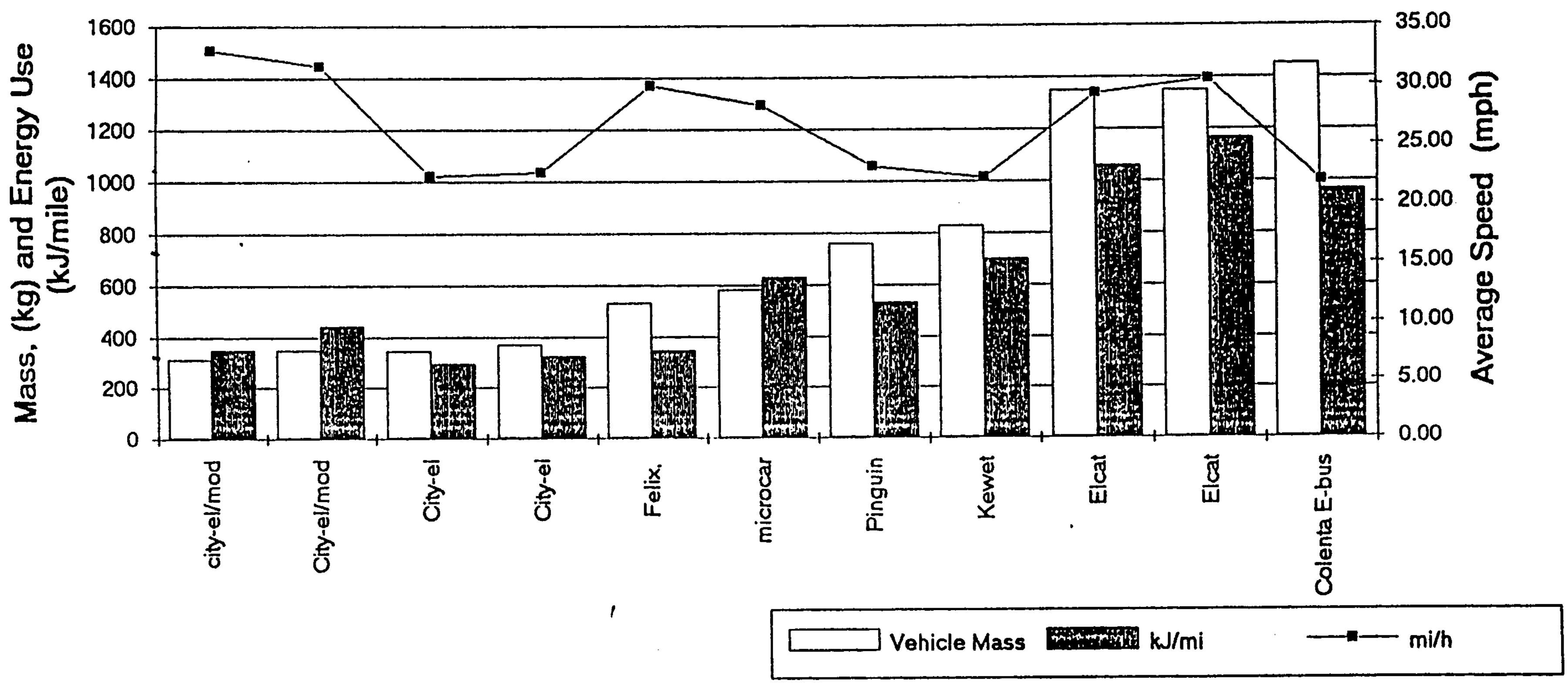
Advantages of NEV Concept

- Modest performance requirements
- Smaller battery pack...
  - fewer weak links (cells in series)
  - longer battery pack life
  - lower battery replacement cost
- Smaller Motor, less power required
- Charge any where without special plugs
- Lower Voltage may mean easier code compliance
- Pollution reductions more significant, since pollution is proportional to energy use
- Replace least efficient use of IC engine cars

Disadvantages of NEV Concept

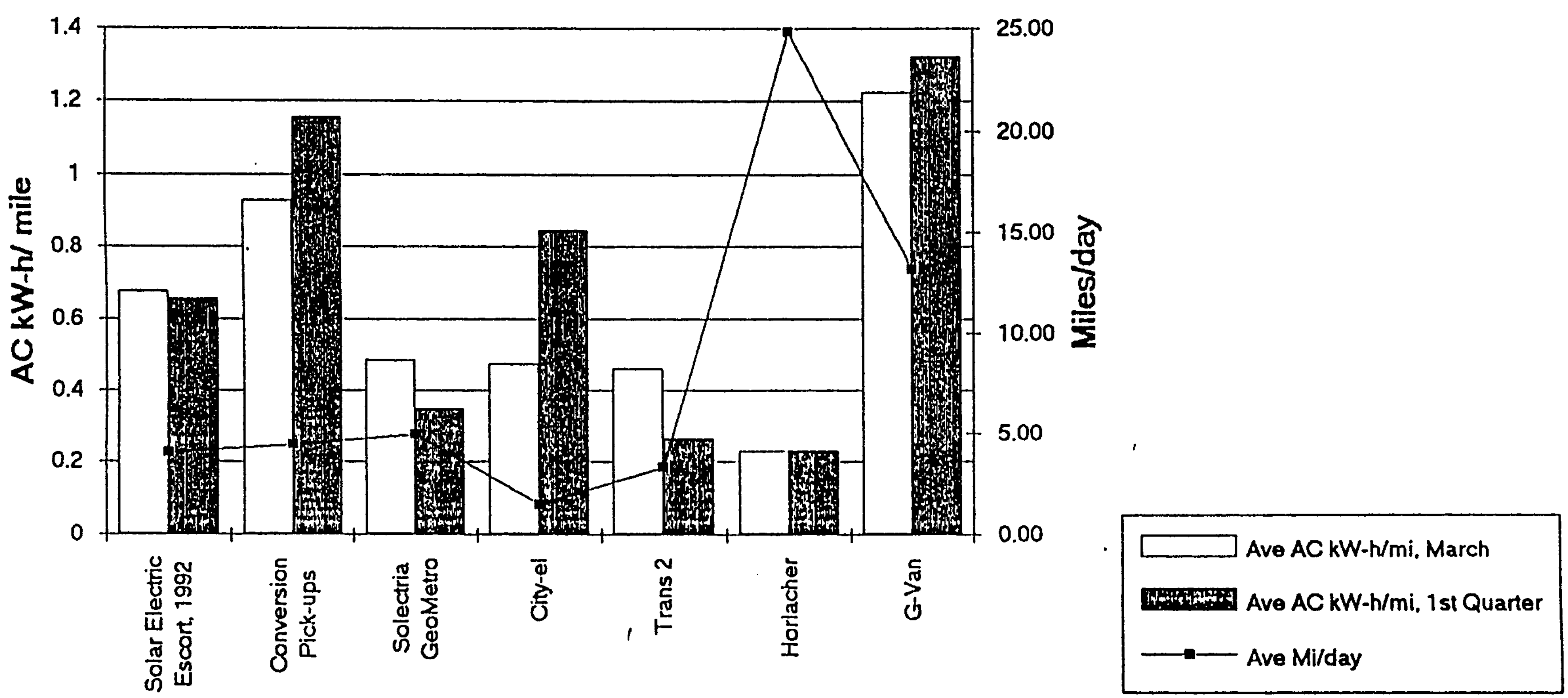
- New Transportation Product, Education required as to which specific needs are met
- NEV needs to be small, and light, we will push personal space envelope
- FMVSS are tailored to larger cars
- Market acceptance will be slower, because of difference in concept
- Product must be in-expensive, price sensitivity is greater than a freeway capable EV

NEV'S @ Solar Cup Denmark, 1993, Results over 177 miles



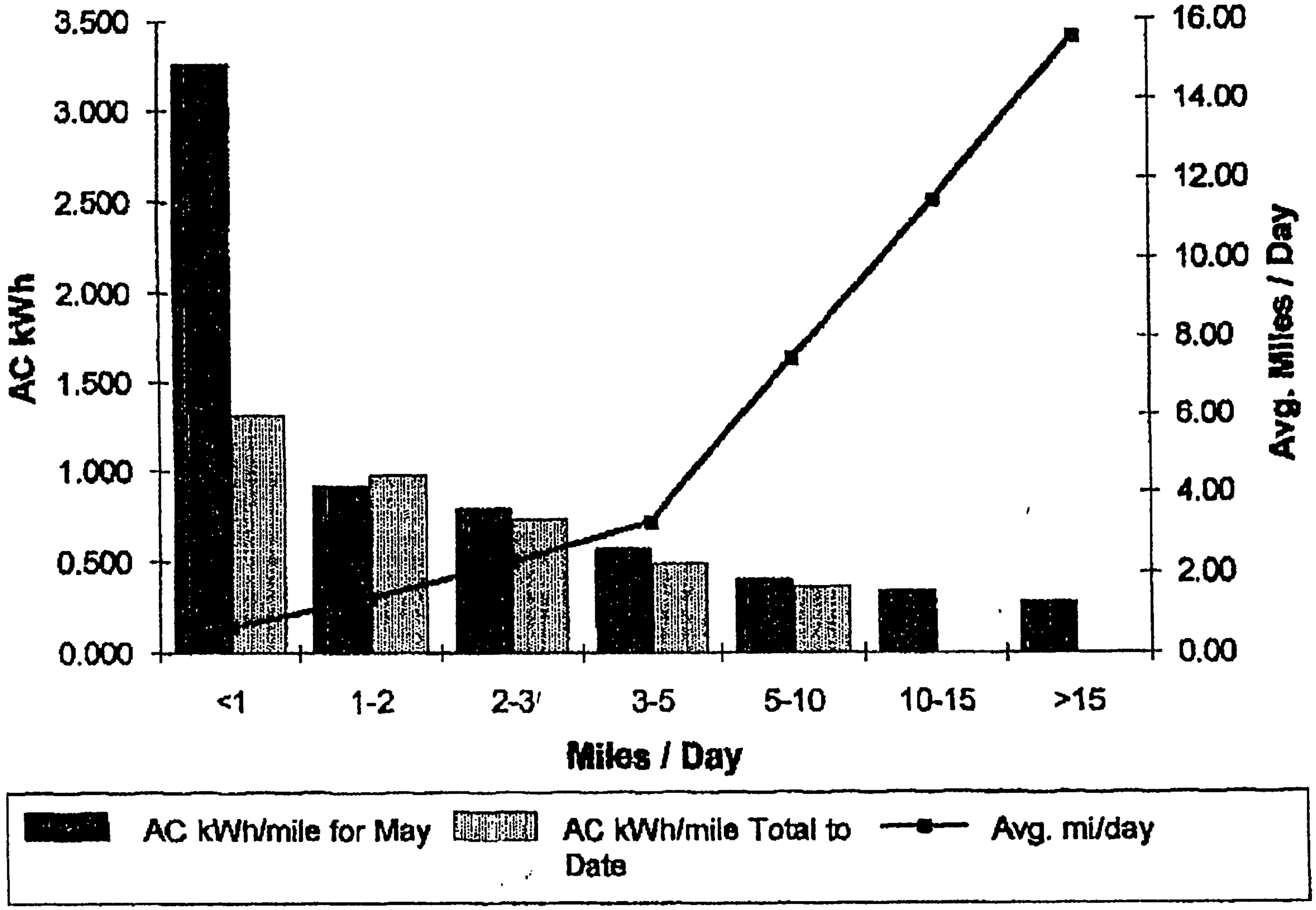
PEV SOLARCU2.XLS Chart 5 6/27/94

Energy Use, Miles driven, SMUD fleet



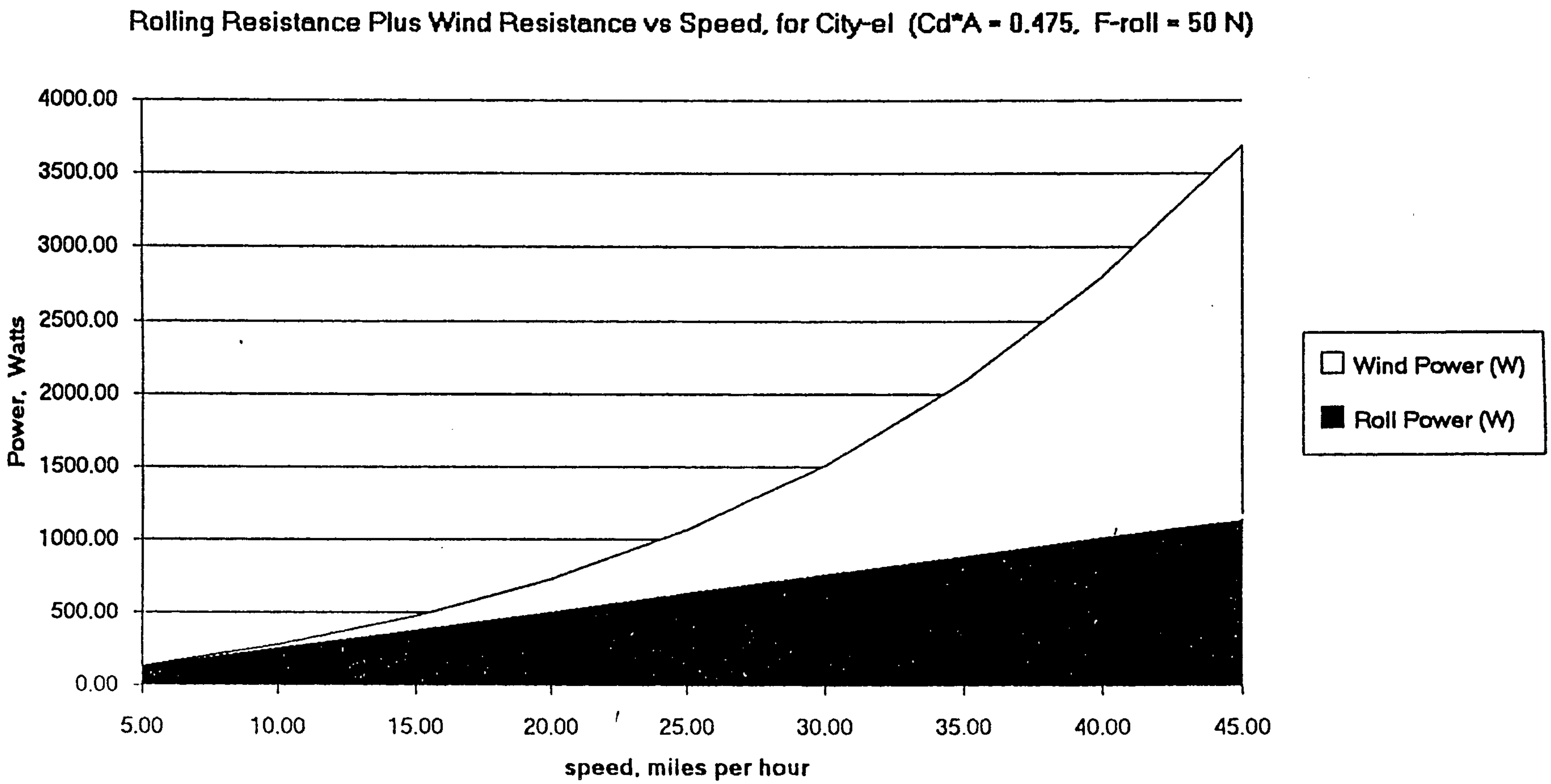
PEV SMUDDATA.XLS Chart 1 6/27/94

City-el Energy Usage



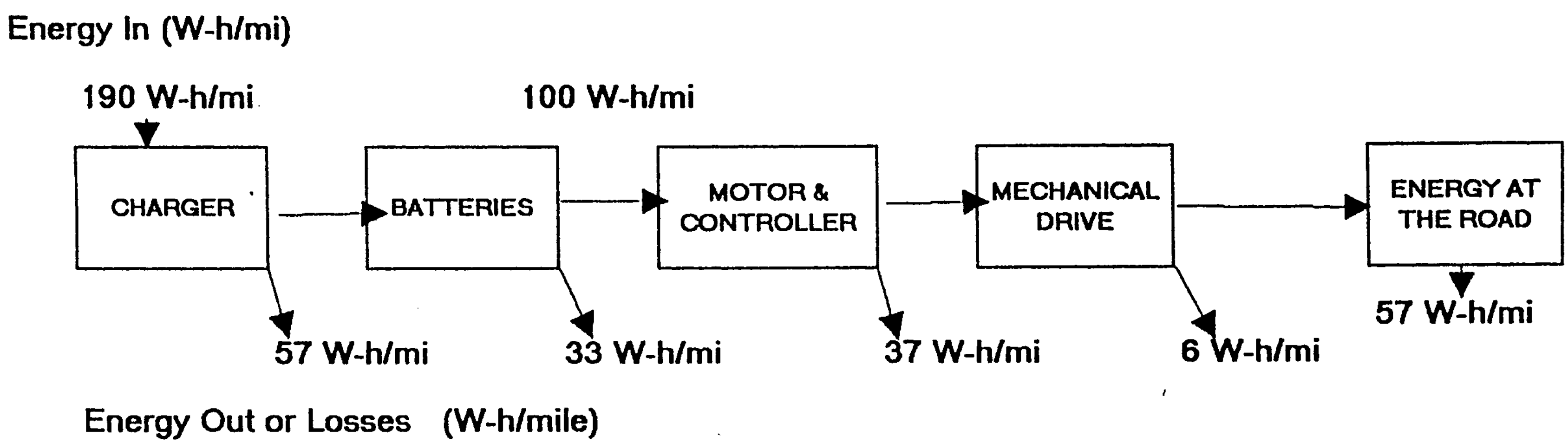
Technical Results

- A System Boundary Definition has been made, and the City-el has been characterized by it's sub-systems
- This shows how Energy is utilitzed in a City-el
- Engineering goals for our new NEV, low energy use vehicle follow the same definition of boundaries... improving on the parts


Rolling Resistance Plus Wind Resistance vs Speed, for City-el (Cd*A = 0.475, F-roll = 50 N)
Power, Watts
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
speed, miles per hour
Wind Power (W)
Roll Power (W)

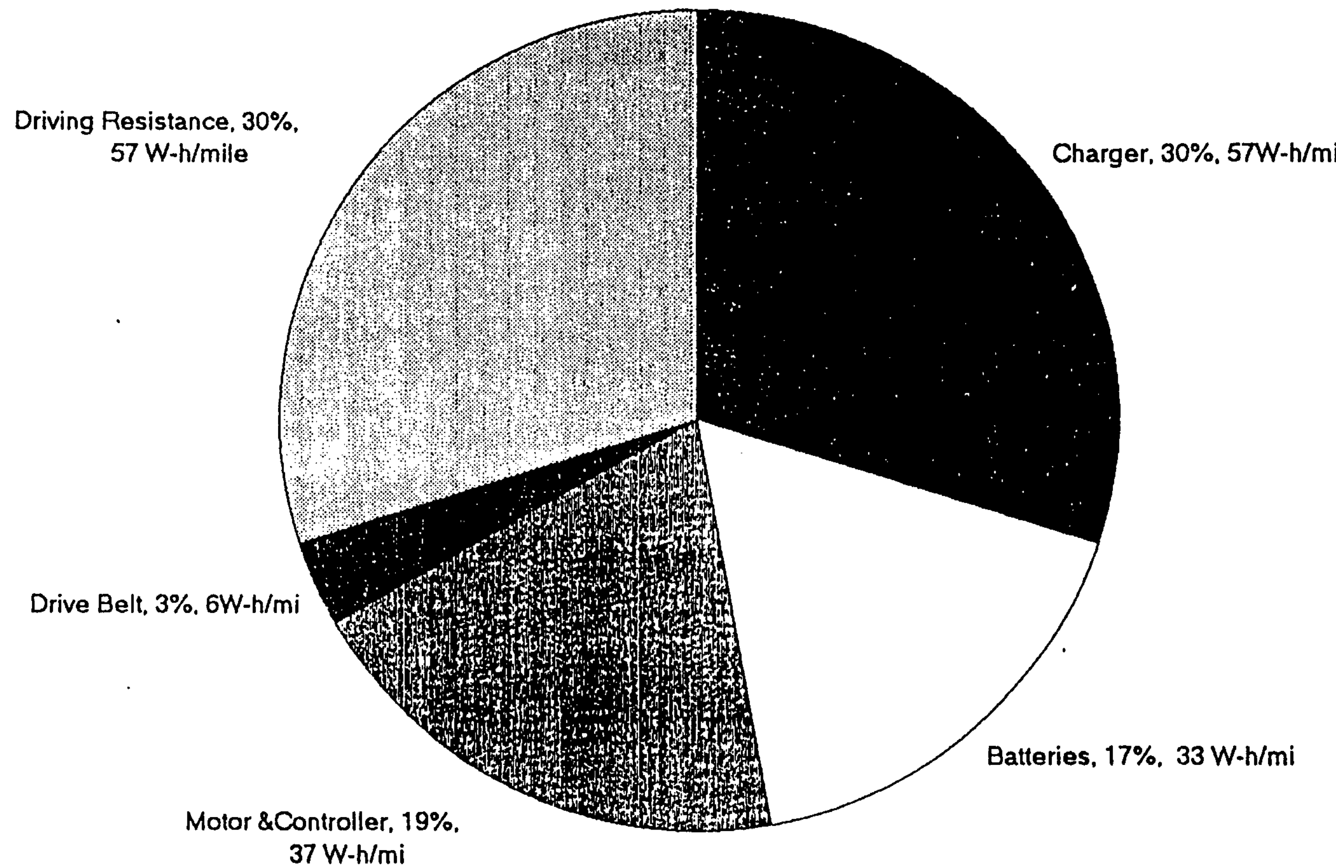
6/27/94

City-el, Average Energy Use of Main Systems

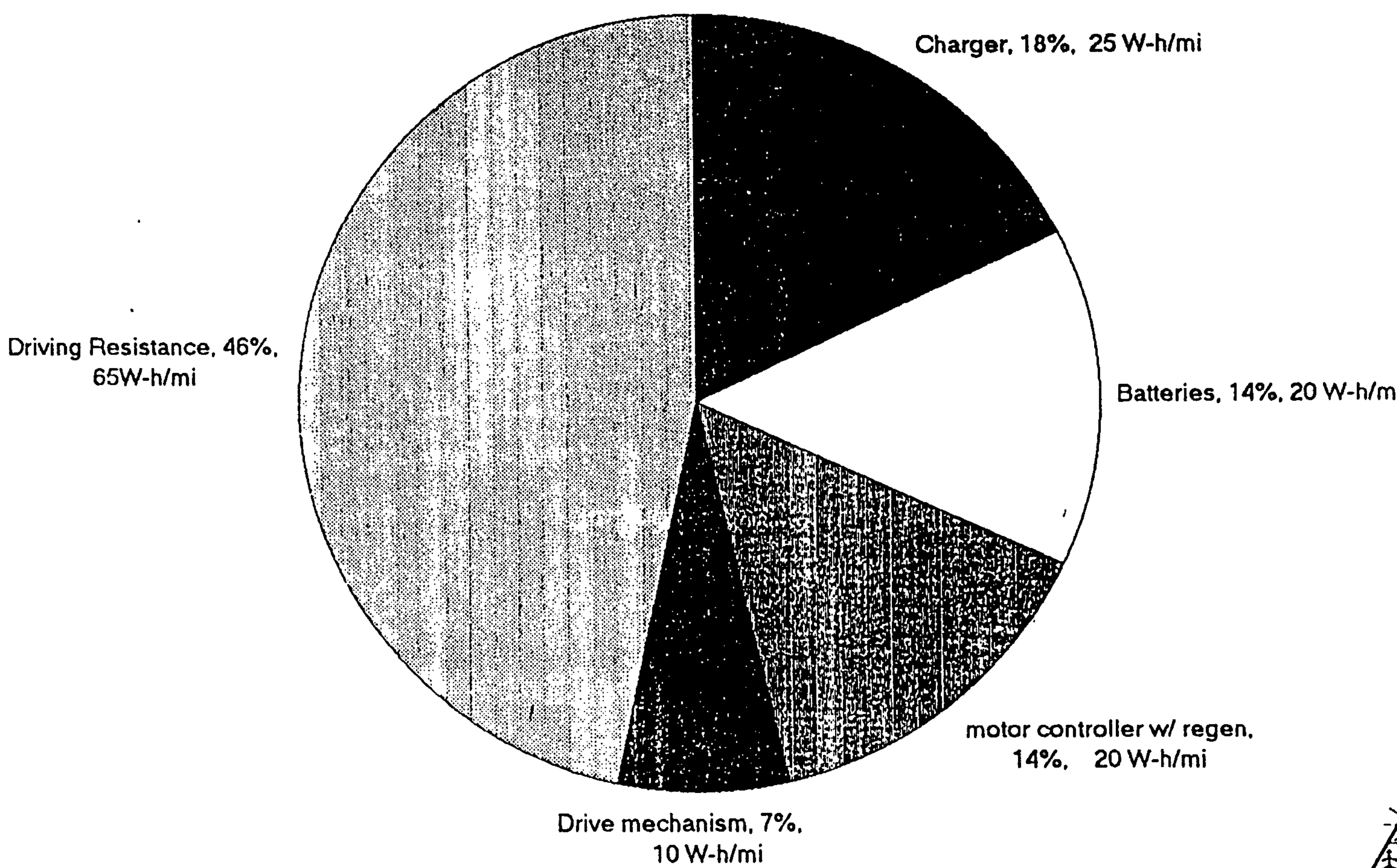


Note, Neglects holding charge and "always on" losses

City-el Systems Energy Use, Average per mile traveled, 190 W-h/mi total at plug



Picador NEV Average Energy Use Engineering Goals, 140 W-h/mi total at plug



PEV CELENRGY.XLS Chart 2 6/28/94

Picador: Vehicle Dynamics

- Mass: 390-440 kg (depending on configuration and batteries)
- Frontal Area: 1.50 m^2
- Cd: 0.3
- Cd*A = 0.45
- Tires: 120/80-16
- Low un-sprung mass (need composite wheels or other suspension components)
- top Speed: 40 mph
- Range 20-40 miles

Picador: Electrical Drive

- 48 V system
- 130-180 kg battery weight
- 3.1-4.3 kW-hour (useful DC) battery capacity
- 5 kW motor (brushless servo drive?)
- Electronic speed limiter
- Regenerative braking

Is pollution proportional to Energy Use?

- I looked at basic requirements for stationary and mobile sources
- Emissions from Stationary sources are measured in PPM in off gas or ng of bad gas per Joule produced
- Emissions for vehicles are measured in g/mile

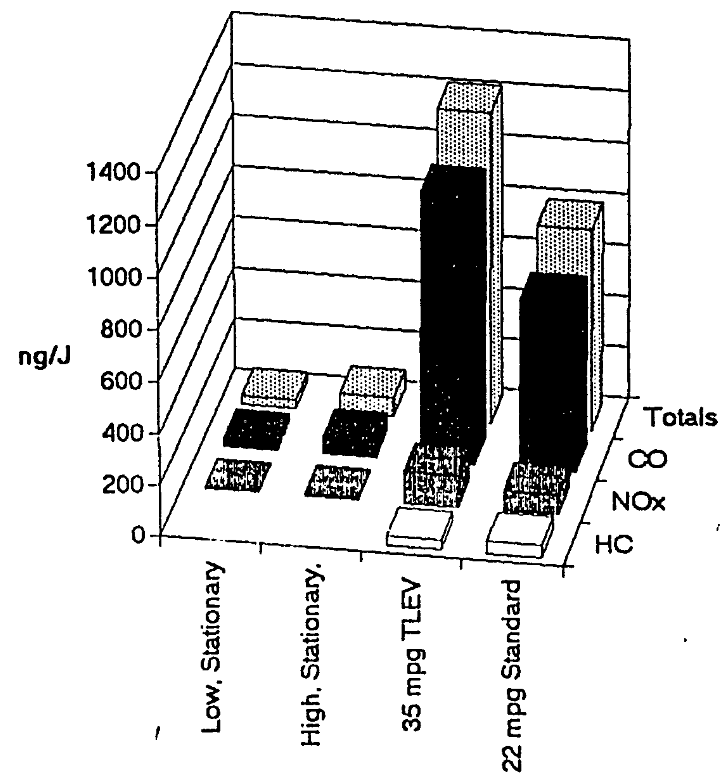
Stationary Sources Basic Data and assumptions

- CO... low 50 PPM to High 100 PPM
- NOx... low 3 PPM to High 10 PPM
- above is at 15% O2 in stack gas
- Assumed 40MJ/kg fuel energy
- Assumed stoichiometry of 14.5 kg air / kg fuel
- Assumed Process operates at 1.75 times stoichiometry to achieve excess O2
- Result: 35-72 ng pollutants / Joule produced

Mobile Sources, basic Data and assumptions:

- CO ... 3.4 g/mile
- NOx ... 0.4 g/mile
- HC ... 0.125 for TLEV
- HC ... 0.250 for standard car
- Stoichiometry: TLEV - 1.2
- Stoichiometry: Standard - 1.1
- O_2 in exhaust: 3% TLEV, 1.5% Standard
- MPG: 35 for TLEV, 22 for Standard car
- Result: 1211 ng / Joule for TLEV, 784 ng / J Standard car...

Emissions permitted, stationary vs. Mobile Sources

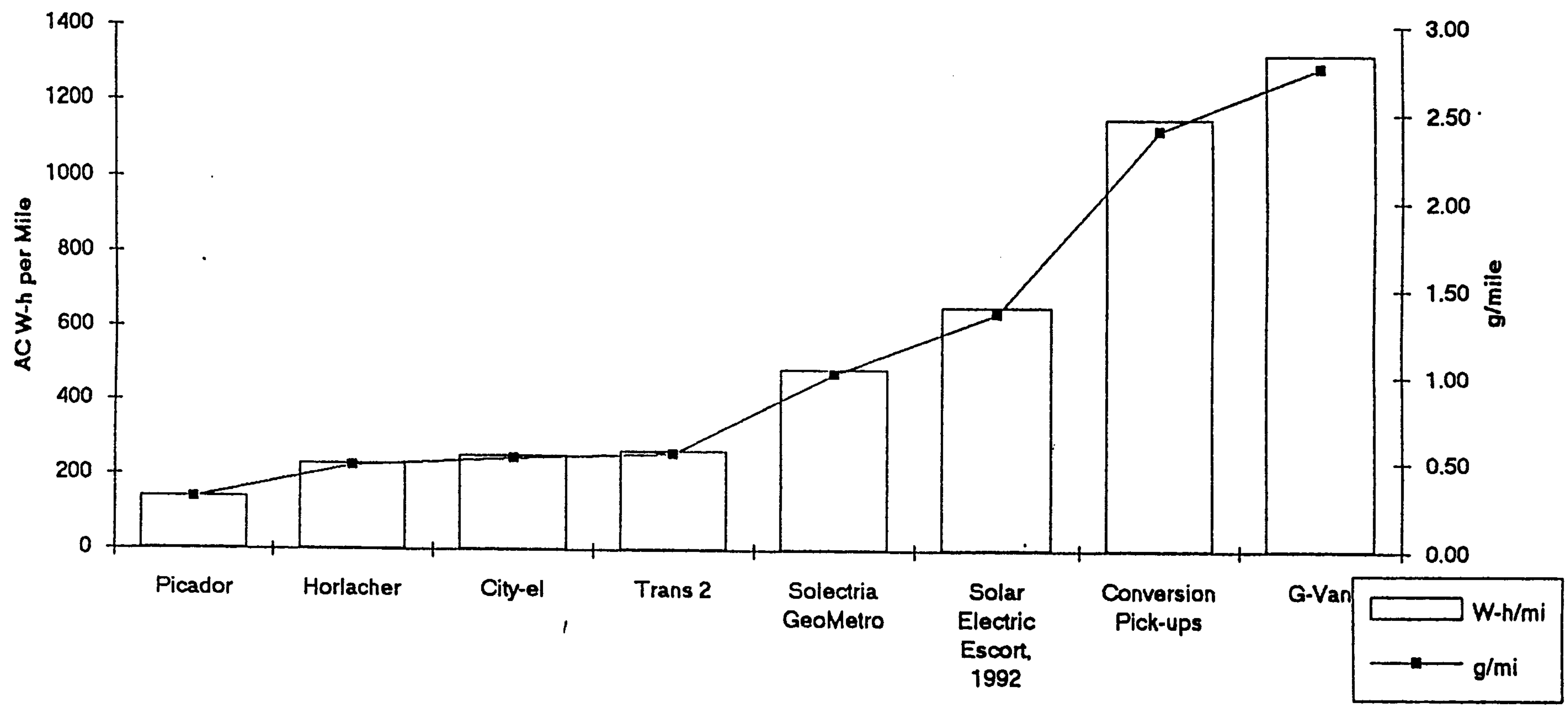


PEV 6/28/94 GAS.XLS Chart 3

Emissions... equivalent for EV's

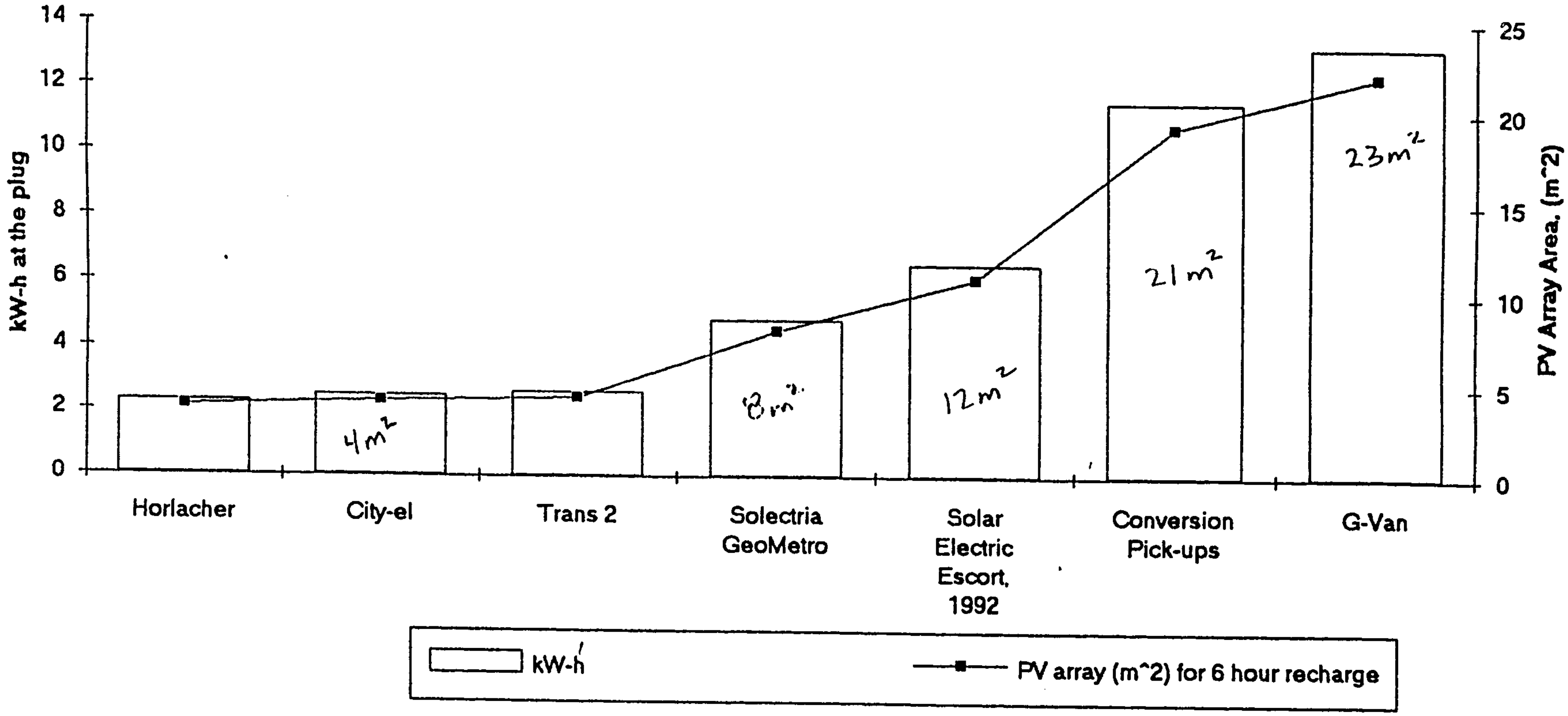
- It is pretty easy to multiply ng/J by energy per mile to get equivalent pollutants
- At the power plant, the energy produced must be distributed to where it is used...
- So I assumed:
- 75% transmission losses, and
- 50 % efficiency of fossil fuel to electricity at the power plant

Energy Use and Emissions for EV's



PEV 6/28/94 SMUDDATA.XLS Chart 5

Energy use for 10 miles, with PV array area for 6 hour recharge



PEV SMUDDATA.XLS Chart 4 6/27/94

Summary:

- A light vehicle which meets consumers needs is possible, it will be more like an improved City-el than a normal car... more utility, more comfort, and a little faster than the City-el
- NEV's use less energy, have fewer batteries, and will cost less than fully capable electric cars
- The Air Quality benefits of NEV's are larger than other EV's
- Final note: Crash safety is our biggest hurdle, this problem is the focus of our present chassis work... a low mass suit of armor!

Test Report, City-el DC to DC Converter Efficiency.

29 September, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

TEST REPORT: City-el DC to DC Converter Efficiency.
Prepared by: Lance Atkins, Pacific Electric Vehicles, 9-29-94

Purpose: The DC to DC converter efficiency curve is documented as well as the power required to run many of the City-el accessories.

Scope: Test methodology and results are described below. Descriptions of the attached spreadsheet and chart are also provided. Refer to the appendix for the spreadsheet and the chart.

Results: The DC to DC converter averages 87.5% efficiency once the output power goes above 23 Watts. In the worst case, the efficiency is 44.4%. This occurs when the key is turned on and no other accessories are being used. Running all of the driving lights takes 79 Watts and occurs at the peak efficiency of about 89%. Variation from City-el to City-el has not been considered in this data.

Test Initial Conditions.

The test was performed at Pacific EV on 8-13-94 by Arthur Cartwright and Lance Atkins. City-el 4135 was used as the test vehicle.

Test Setup and Procedure

In order to measure the input and output power from the DC to DC converter, an amp meter was placed in each line. The Micronta multimeter was used to measure the input current, and the Kelvin multimeter was used to measure the output current. Voltage for each line was measured using the Fluke multimeter. Refer to Figure 1 in the appendix for a schematic of this test setup.

Test Equipment.

Equipment	Model	S/N
Vehicle	City-el	4135
Multimeter	Fluke 21 Series II Multimeter	58570412
Multimeter	Kelvin 400 LE	24001215
Multimeter	Micronta No 22-182	CJ062859

Once the meters were in place, various accessories were turned on first singly and then simultaneously. In each case, readings on the multimeters were recorded while the accessories were on. Since there was only one voltmeter, this meter was moved from one location to another. This means that the voltage readings are not simultaneous.

Data Descriptions

Data from the test was entered in the spreadsheet titled City-el DC to DC Converter Efficiency Test. This is Pacific EV file DCTODC.XLS. See the appendix for a copy of this spreadsheet. Power was computed using the formula (voltage*current) with the result in Watts. Efficiency was computed using the formula (power out/power in). The power used by various accessories can be see here. It should be noted that the fan, heater, and windshield wiper are 36 volt accessories. The 12 volt load from these devices comes from running relays.

From the spreadsheet described above, The chart City-el DC to DC Converter Efficiency was generated. See the appendix for this chart. The data for the chart was taken from the % Eff. column of the spreadsheet. Over the plateau of the curve efficiency averages 87.5%. The average over the entire curve is 75.1%. However, most accessory operations occur in the plateau of the curve.

APPENDIX

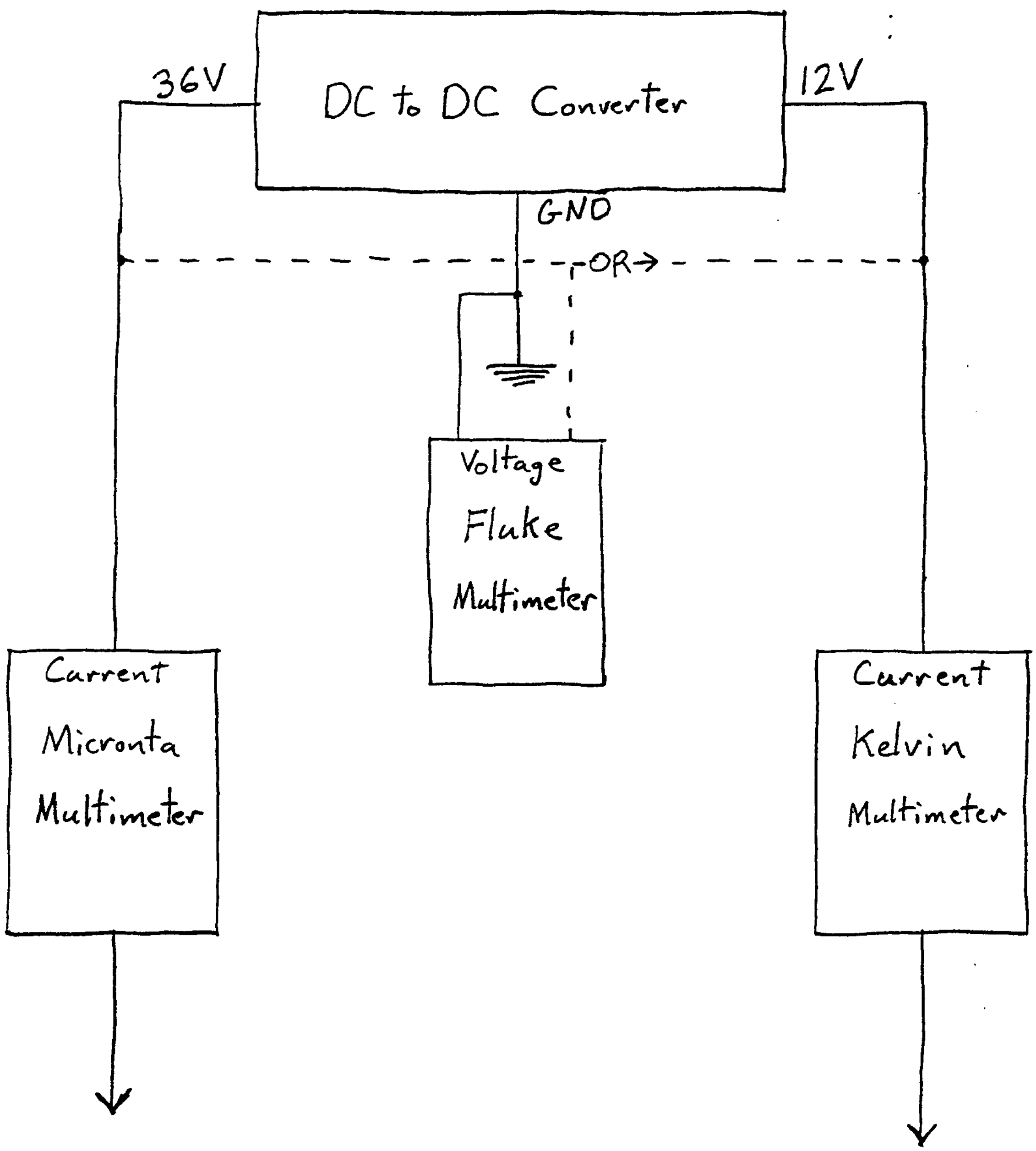


Figure 1: City-el DC to DC Converter Test Setup.

City-el DC to DC Converter Efficiency Test

Date: 8-13-93

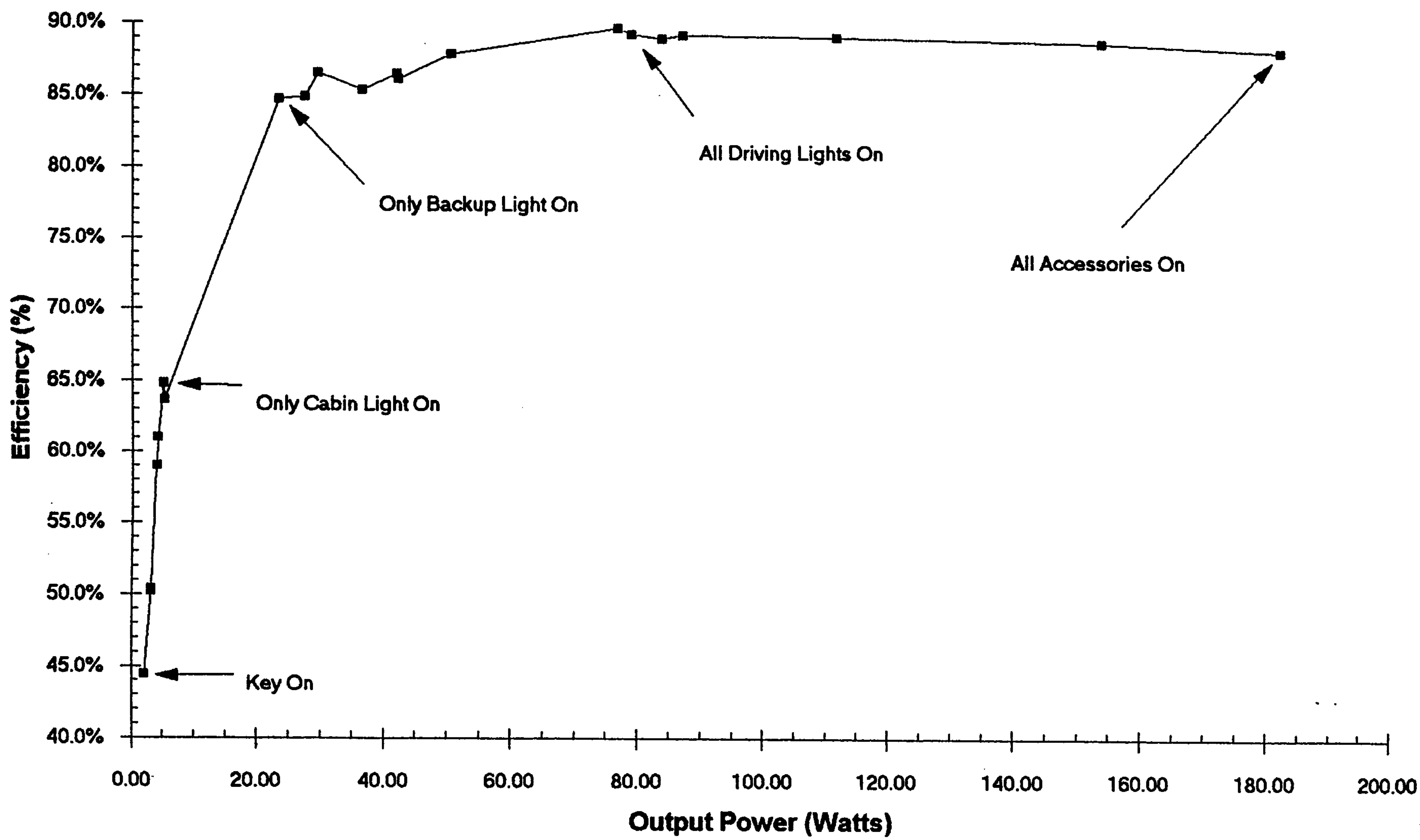
Number	Accesories On	12 Volt Out Voltage	12 Volt Out Current	12 Volt Out Power	36 Volt In Voltage	36 Volt In Current	36 Volt In Power	% Eff.	Comments
	Units-->	volts	amps	Watts	volts	amps	Watts	%	
1	Key On	12.57	0.17	2.14	37	0.13	4.81	44.4%	
2	Fan Low Heater Low	12.57	0.25	3.14	36.7	0.17	6.24	50.4%	
3	Fan High	12.58	0.25	3.15	36.8	0.17	6.26	50.3%	
4	Fan Low	12.58	0.25	3.15	36.7	0.17	6.24	50.4%	
5	Windshield Wiper	12.57	0.31	3.90	36.7	0.18	6.61	59.0%	
6	Fan Low Heater High	12.57	0.32	4.02	35.9	0.19	6.82	59.0%	
7	Fan High Heater Low	12.57	0.33	4.15	35.8	0.19	6.80	61.0%	
8	Fan High Heater High	12.58	0.4	5.03	35.3	0.22	7.77	64.8%	
9	Cabin Light	12.57	0.41	5.15	36.8	0.22	8.10	63.7%	
10	Backup Light	12.57	1.86	23.38	36.8	0.75	27.60	84.7%	
11	Parking Lights	12.57	2.18	27.40	36.7	0.88	32.30	84.8%	
12	Windshield Washer	12.57	2.35	29.54	36.7	0.93	34.13	86.5%	
13	Parking Lights*	12.57	2.9	36.45	36.5	1.17	42.71	85.4%	
14	Left Turn Signal	12.57	3.34	41.98	36.5	1.33	48.55	86.5%	Max reading
15	Right Turn Signal	12.57	3.36	42.24	36.6	1.34	49.04	86.1%	Max reading
16	Brake Lights	12.56	4.02	50.49	36.6	1.57	57.46	87.9%	
17	Hazard Lights	12.56	6.12	76.87	36.3	2.36	85.67	89.7%	Max reading
18	All Driving Lights on	12.56	6.29	79.00	36.4	2.43	88.45	89.3%	
19	Brake Lights*	12.56	6.67	83.78	36.2	2.6	94.12	89.0%	
20	All Driving Lights on*	12.56	6.94	87.17	36.3	2.69	97.65	89.3%	
21	Parking Lights & Brakes *	12.55	8.9	111.70	36.1	3.47	125.27	89.2%	
22	All Driving Lights & Brakes*	12.54	12.27	153.87	35.8	4.84	173.27	88.8%	
23	#22 with Backup Lights & Washer	12.54	14.55	182.46	35.6	5.81	206.84	88.2%	

* Includes the original City-el tail / brake lights in addition to the Peterson lights.

Total Average: 75.1%

Plateau Average Starts with # 10: 87.5%

City-el DC to DC Converter Efficiency



APPENDIX

Order of Appendix Contents: Page Designation:

Pre-Test Trips and Charges.

Test Information

Figures

Spreadsheets

Graphs

Chart 8: Specific Gravity for City-el 4135 Charged on 9-11-94

From Spreadsheet: City-el 4135 Charger and Battery Test. **Pacific EV file**: C1352544.XLS.
Data from Columns Titled:
X Category 1: Specific Gravity Section, Batt 1
X Category 2: Specific Gravity Section, Batt 2
X Category 3: Specific Gravity Section, Batt 3

Specific gravity readings for immediately before charging and 44 hours after charging are shown. Battery 3 which had the highest voltage during the charging cycle also exhibits the highest specific gravity. The specific gravity readings are probably good to plus or minus 0.005.

Chart 5: Charge Profiles for City-el 4135 as Recorded by the DAS on 9-11-94

From Spreadsheet: City-el 4135 Charger Test. **Pacific EV file**: CHRGANAL.XLS.
Data from Columns Titled: X Axis: Minutes
Y1: DAS Data Section, Deg C
Y2: DAS Data Section, V
Y3: DAS Data Section, A

Minute by minute averages recorded by the DAS are plotted for pack voltage, charging current, and battery temperature. The battery temperature was measured against the case on the positive end of battery 3. The small wiggle in the voltage curve begins at 132 minutes and continues until 137 minutes. At 137 minutes, the 82% light on the Mini-el diagnosis box came on. This wiggle can also be seen in the charge current curve. The spikes in the charge current curve during the high current part of the charge are actually there. See Chart 2: Charge Current for City-el 4135 on 9-11-94 for a clearer view. As discussed in the description of that chart there is some error between the DAS current shown here and what the manually recorded data gives.

Chart 6: Charge Output Power and Efficiency for City-el 4135 on 9-11-94

From Spreadsheet: City-el 4135 Charger and Battery Test. **Pacific EV file**: C1352544.XLS.
Data from Columns Titled: X Axis: Minutes
Y1: DC Power
Y2: Charge eff.

The curves for the output power and efficiency (power out/ power in) of the City-el charger are shown. Note that the efficiency is given as a decimal instead of a percent so that it fits on the kilowatt scale. The efficiency curve is fairly flat averaging 53%. This is quite poor when compared to the Solectria solid state charger that averaged 93% efficiency.

Chart 7: Voltage Variation of Batteries During Charge of City-el 4135 on 9-11-94

From Spreadsheet: City-el 4135 Charger and Battery Test. **Pacific EV file**: C1352544.XLS.
Data from Columns Titled: X Axis: Minutes
Y1: Batt 1
Y2: Batt 2
Y3: Batt 3
Y4: Avg. V

Individual battery voltages during the charge are shown. The typical voltage variation is less than 1 tenth of a volt between the highest and lowest battery. The maximum variation of 0.43 volts was recorded 15 minutes after the 82% light on the Mini-el diagnosis box lit.

meter seems to read too high during the high current phase of the charge. Once again the DAS hourly average data falls right on the charge line except for the last data point which falls too low because of the zero amps that are averaged into this data point.

Chart 3: Charge Temperature for City-el 4135 on 9-11-94

From Spreadsheet: City-el 4135 Charger Test. **Pacific EV file**: CHRGANAL.XLS.
Data from Columns Titled: X Axis: Minutes
Y1: DAS Data Section, Deg C
Y2: Manual Data Section, Deg C
Y4: DAS Hourly Average Data Section, Deg C

Temperature changes of battery 3 or the passenger side battery are shown. Only the DAS and the manual data include data to be plotted in this chart. In short this shows that a better method of manually measuring temperature must be found. A partial submersion thermometer sitting on the battery post is not adequate. The DAS data is probably more accurate than the manual data because the system was originally checked by Jose Baer during design of the DAS and was found to be quite accurate. Furthermore, the DAS curve follows a path that would be expected. Finally, the partial submersion thermometer has not been insulated from the atmosphere so some effect could be expected. The partial submersion thermometer method was used for the Solectria Force Charger and Battery Test so similar errors could probably be expected in that test as well. The steps in the DAS curve are the digital steps of the DAS for every tenth of a volt.

Chart 4: Charge Energy for City-el 4135 on 9-11-94

From Spreadsheet: City-el 4135 Charger Test. **Pacific EV file**: CHRGANAL.XLS.
Data from Columns Titled: X Axis: Minutes
Y1: DAS Data Section, Wh
Y2: Manual Data Section, Wh
Y3: Cruising Equipment Data Section, Wh

The Watt-hours used during the charge as recorded by the DAS, manual equipment, and the Cruising Equipment meter are shown. The DAS and the manual data read the Hydria meter which shows the AC energy used while the Cruising Equipment meter measures the DC energy delivered to the batteries. Comparison of the DC Watt-hours computed from the manual data and the Cruising Equipment meter show a 14% error. This error is not unreasonable given the inaccuracies of computing the Watt-hours from the half hour interval manual data. See the spreadsheet titled City-el 4135 Charger and Battery Test for more information on this. The DAS does read the Hydria Watt-hour counter correctly once the noise from the transformer is reduced by relocating the Hydria meter. This should provide a bench mark for the final positioning of the completed DAS system.

Chart Descriptions

From the spreadsheets described above, several graphs were generated. These graphs are described and discussed in the following list. Each graph description begins with the name of the spreadsheet it comes from and the names of the columns used to generate the graph. Refer to the appendix for these charts.

Chart 1: Charge Voltage for City-el 4135 on 9-11-94

From Spreadsheet: City-el 4135 Charger Test. **Pacific EV file**: CHRGANAL.XLS.
Data from Columns Titled: X Axis: Minutes
Y1: DAS Data Section, V
Y2: Manual Data Section, V
Y3: Cruising Equipment Data Section, V
Y4: DAS Hourly Average Data Section, V

The charge voltage curves as measured by the DAS, manual equipment, Cruising Equipment meter, and the saved DAS average are shown. The manual data agrees very well with the DAS. The Cruising Equipment meter reads very slightly high but it is still quite close. In fact, the error falls with in the resolution of the meter which reads to the nearest half a volt. The DAS average data falls almost exactly on the line once the hourly average is plotted at the middle of the hour. As would be expected, some of the detail in the curve is lost with the hourly averages. The last data point does not fall on the line, however, because lower voltages after the charge is over have been averaged into the data point. This should be remembered when analyzing charge data stored in the DAS. The chart shows that all the instruments agree on the voltage.

Chart 2: Charge Current for City-el 4135 on 9-11-94

From Spreadsheet: City-el 4135 Charger Test. **Pacific EV file**: CHRGANAL.XLS.
Data from Columns Titled: X Axis: Minutes
Y1: DAS Data Section, A
Y2: Manual Data Section, A
Y3: Cruising Equipment Data Section, A
Y4: DAS Hourly Average Data Section, A

Charging current curves are shown. Data has been plotted from the DAS, manual equipment, Cruising Equipment meter, and the internally stored DAS data. There is a relatively constant error between the manual data and the DAS data. It seems most likely that this is a DAS calibration error. An error of this magnitude may be quite common since the voltage reading that is entered during the calibration procedure must be delayed by exactly 1 second in order to coincide with what the DAS is seeing. In practice this is quite difficult to do. This area should be explored further to determine how common and how large this error tends to be. Generally, the Cruising Equipment meter reads correctly within its ability to measure to the nearest amp. For some reason though, the

V — Pack voltage as measured by the Sensitive Research voltmeter. See Pack V column of City-el 4135 Charger and Battery Test spreadsheet.

A — Charge current in amps as measured by the Fluke reading of the mV reading of the City-el charge shunt. See Amps column of City-el 4135 Charger and Battery Test spreadsheet.

Cruising Equipment Data Section

Wh — Watt-hours used since the beginning of the charge. See KWH column of City-el 4135 Charger and Battery Test spreadsheet.

V — Pack voltage as measured by the Cruising Equipment meter. See Volts column of City-el 4135 Charger and Battery Test spreadsheet.

A — Charge current as measured by the Cruising Equipment meter. See Amps column in Cruising Equipment Meter section of City-el 4135 Charger and Battery Test spreadsheet.

DAS Hourly Average Data Section

Note: This data has been placed in the middle of the hour. For example, the data that was recorded at the end of the first hour or 60 minutes has been placed at the 30 minute location since it is the average for the hour. The data has been pulled from DAS file D1352544.1DS. It is the third charge.

Deg C — Temperature of number 3 or passenger side battery saved internally in the DAS.

V — Pack voltage saved internally in the DAS.

A — Charge current saved internally in the DAS.

W-h used — This gives the Watt hours used since the last data point. It is computed using the formula: [(current W-h read)-(previous W-h read)]*0.9. The 0.9 is a correction factor for the Hydria KWH meter which reads 10% too high on the Watt hour counter.

Man. Wh — Computes the Watt-hours used from the manual data using the following formula: Pack V*Amps*[(current minutes-previous minutes)/60]+previous Man. Wh reading. This method reads slightly low because the voltage and current at the end of the time period are used instead of an average.

% Diff. — Computes the percent difference between the Man. Wh and the Cruising Equipment KWH readings. The formula used is [(KWH*1000)-Man. Wh]/(KWH*1000).

Spreadsheet: City-el 4135 Charger Test.

<u>Column Title</u> — <u>Data Description</u>

<u>DAS Data Section</u>

Minutes — Gives the elapsed minutes since the beginning of the charge. There may be a maximum 3 minute synchronization problem between the DAS data and the manual and Cruising Equipment data. The data has been matched at the charge ending time which should have reduced the synchronization error to about 1 minute or less.

Wh — Watt-hours used since the beginning of the charge.

Deg C — Temperature of the number 3 or the passenger side battery as measured by a thermistor placed against the case on the positive terminal end. The thermistor was insulated from the ambient temperature.

V — Pack voltage as measured by the DAS.

A — Charge current in amps as measured by the DAS.

<u>Manual Data Section</u>

Wh — Watt-hours used since the beginning of the charge. See Watt hour column of City-el 4135 Charger and Battery Test spreadsheet.

Deg C — Temperature of the number 3 or passenger side battery as measured by the SPER Scientific partial submersion thermometer sitting on the negative post. See Temp. C column of City-el 4135 Charger and Battery Test spreadsheet.

Batt 1	Voltage of the left hand or drivers side battery.
bubble?	Indicates whether there are visual signs of gassing in the batteries.
Batt 2	Voltage of the center battery.
Batt 3	Voltage of the right hand or passengers side battery.

Cruising Equipment Meter Section

Amps	Charge current as indicated on the display.
Volts	Battery pack voltage as indicated on the display.
kWh read	Kilowatt-hour reading shown on the display.
KWH	Computes the number of kilowatt-hours used since the charge began using the formula: (current kWh read)-(starting kWh read).

Specific Gravity Section

Batt 1 - Batt 3	Specific gravity readings are given for each battery. The readings are eyeball averages of all six cells. These readings are probably accurate to +/- 0.005

Data Analysis Section

Sum of V	Is computed as the sum of all of the individual battery voltages from battery 1 through battery 3.
Difference	Computed using the formula: (Pack V) - (Sum of V). This indicates the accuracy between the individual battery voltage readings and the pack voltage reading.
Avg. V	Is the computed average of all the battery voltages from battery 1 through battery 3.
Stdev. V	Is the standard deviation for each of the average voltages recorded in Avg. V.
Max Diff.	This gives the voltage difference between the highest and lowest batteries.
DC Power	Computed using the formula: [(Pack V)*(Amps)]/1000. The result is in kilo Watts.
Charge eff.	Computed using the formula: (DC Power)/(kilo Watts).

Spreadsheet Data Descriptions

The manually recorded test data was entered in the spreadsheet titled City-el 4135 Charger and Battery Test. This is Pacific EV file C1352544.XLS. Minute by minute DAS data on the Watt-hours, temperature, voltage, and current was entered in the spreadsheet titled City-el 4135 Charger Test. This is Pacific EV file CHRGANAL.XLS. Corresponding manual data, Cruising Equipment meter data, and hourly averaged DAS data were also entered in this spreadsheet. See the appendix for a copy of these spreadsheets. The following lists give each column title and an explanation of the data contained in that column.

Spreadsheet: City-el 4135 Charger and Battery Test.

Column Title	Data Description
Manual Data Section	
Date	Gives the date of the data.
Time	Gives the 24 hour time of the data.
Minutes	Gives the elapsed minutes of the charge test.
Pack V	Battery pack voltage as measured from the Sensitive Research Voltmeter.
kilo Watts	Input power to the charger recorded from the Hydria KWH meter
W-h read	Watt-hour reading recorded directly from the Hydria KWH meter.
Watt hour	Computes the Watt-hours used since the start of the charge using the formula: [(current W-h read)-(starting W-h read)]*0.9. The 0.9 is a correction factor for the Hydria KWH meter which reads 10% too high on the Watt hour counter.
Line V	AC line voltage recorded from the Hydria KWH meter.
Shunt mV	Milivolt reading across the City-el Charge shunt as measured by the Fluke multimeter. The Mini-el Diagnosis box was used to provide convenient access to the charge shunt (3.3 mV/A)
Amps	Computes the output current of the charger using the formula: (Shunt mV)/3.3. This is based on the City-el charge shunt value of 3.3 mV/A.
Temp. C	Degrees Celsius of the number 3 or passenger side battery as measured by the SPER Scientific partial submersion thermometer sitting on the negative post.

Test Equipment.

Equipment	Model	S/N
Charger	City-el Standard	--
KWH meter	Cruising Equipment KWHT+12	227
Data Acquisition	Pacific EV Prototype DAS	--
Multimeter	Fluke 21 Series II Multimeter	58570412
Voltmeter	Sensitive Research Instrument Corp. Model C	942135
KWH meter	Hydria KWH Meter ST2400A	--
Diagnosis Box	Mini-el Diagnosis Box	--
Shunt	City-el Charge Shunt 3.3 mV/A	--
Thermometer	SPER Scientific 76mm X 1mm Mercury	--
Watch	Casio Tri Graph 827 TGW-10	--
Hydrometer	Plews 70-051	--

To begin taking data the computer was attached to the DAS and the charger was plugged in. This was necessary to in order to put the DAS into the charge monitoring mode. Manual data was taken immediately after getting the computer setup to record minute by minute averages. Typically the manual data collection followed the following procedure. During the 45 seconds before the recorded time, the temperature, pack voltage, and line voltage were taken. At exactly the recorded time, the Watt-hour counter reading was noted. This was followed by the shunt mV reading, battery 1 voltage, battery 2 voltage, battery 3 voltage, and the Cruising Equipment meter readings. Finally, the batteries were inspected for signs of gassing. The whole process took approximately 4 minutes.

Test Initial Conditions.

This test was performed in Carmichael on City-el 4135 with the original Trojan 30XH batteries. The City-el had 529.7 miles on it. The Pacific EV prototype DAS with the MINDAS12 EPROM was installed in the vehicle which had been previously wired for the DAS by Pacific EV. See the Pacific EV drawing of the City-el Data Acquisition System for information on the prototype DAS. The DAS was calibrated using the method described in the pre-print version of the DAS User's Manual. The same Fluke 21 series II multimeter used in this test was used for the calibration. To avoid noise problems from the transformer the Hydria meter was moved from the top of the transformer to the floor of the package compartment beside the transformer. Spreadsheets and charts for the previous two charges and trips as recorded by the DAS are provided in the appendix for reference.

Test Setup and Procedure

This test was conducted over the following time period. The initial specific gravity test was taken at 11:31 AM on 9/11/94 immediately following the trip to discharge the City-el. Charging began at 12:00 PM on 9/11/94. About 8 hours later the test ended at 7:50 PM on 9/11/94. Right after charging, the City-el was driven about 300 feet to a new parking place where it stayed until the final specific gravity measurements were taken. Final specific gravity readings were taken about 43.5 hours later.

To prepare for the test, a laptop computer was hooked up to the DAS in order to take the minute by minute averages during the charge. The Cruising Equipment Meter was installed as described in its instructions. Voltage sensor lines were run directly to the positive and negative posts of the battery pack, and current sensor lines were run to the Cruising Equipment shunt (50mV at 500 A) located on the negative side of the battery pack. Twelve volt power was supplied to the meter from the City-el DC to DC converter. The Hydria KWH meter was left attached to the input line of the charge transformer, but was moved from the top of the transformer to the floor of the luggage compartment next to the charge transformer. This was done to avoid noise problems from the charger that affect the DAS kilowatt-hour reading. The Sensitive Research voltmeter was connected to the positive and negative terminals of the battery pack. Finally, the Fluke 21 was used to measure the individual battery voltages, and to measure the City-el charge shunt (3.3 mV/A) voltage using the Mini-el diagnosis box. Temperature was measured manually with a partial submersion thermometer sitting on the negative terminal of battery 3 or the passenger side battery. The DAS used an insulated thermistor placed against the case on the positive end of battery 3. This setup is shown in Figure 1 of the Appendix.

TEST REPORT: City-el 4135 Charger and Battery Test.
Prepared by: Lance Atkins, Pacific Electric Vehicles, 9-27-94

Purpose: The purpose of this test report is several fold. First, it documents the efficiency and performance of the standard City-el charger. Second, it explores the voltage variation of the batteries during the charge cycle and the subsequent charge as measured by the specific gravity. Third, it bench marks the Pacific EV prototype DAS (Data Acquisition System) for comparison to the final version of the DAS. Fourth, it compares the hourly averages stored in the DAS with the minute by minute averages of the DAS. This should aid in evaluating the charge data acquired from other vehicles once the DAS systems have been installed. Fifth, it compares the accuracy of the DAS, the Cruising Equipment Meter installed in 4135, and the hand-held instruments.

Scope: The test set-up, measuring equipment, and test procedure for the test are discussed below. Explanations of the spreadsheet quantities and attached graphs are also provided. See the Appendix cover page for a list of the attached figures, spreadsheets, and graphs.

Results: Average efficiency for the City-el standard charger was found to be 53%. Very detailed charging curves are availiable for comparison to other chargers in the chart titled Charge Profiles for City-el 4135 as Recorded by the DAS on 9-11-94. Voltage variation between batteries was typically less than 0.1 volts. Battery 3 which had the highest voltage during the charging process also exhibited the highest stabilized specific gravity. The Pacific EV prototype DAS performed very well and will provide a good reference mark for the final DAS installation and performance. The DAS internally-stored, hourly-average data fits the actual charge curve well except for some loss of detail. There is also a small problem with the last data point on the voltage and current curves. Lower voltages and currents after the end of the charge tend to drag the data point below the actual value. Accuracy between all three types of instruments used was quite good with three exceptions. First, the DAS charge current was consitently high, probably due to a calibration error. This error should be investigated further to determine how common it is and what effect there might be on the DAS data from the other City-els. Second, for some unknown reason, the Cruising Equipment meter current reading was too high during the high current part of the charge. Third, the manual temperature measurement method needs to be improved. The DAS system was calibrated during design and reads quite differently from the manual method. Overall, the test results appear to be quite accurate.

Test Report, City-el 4135 Charger and Battery Test.

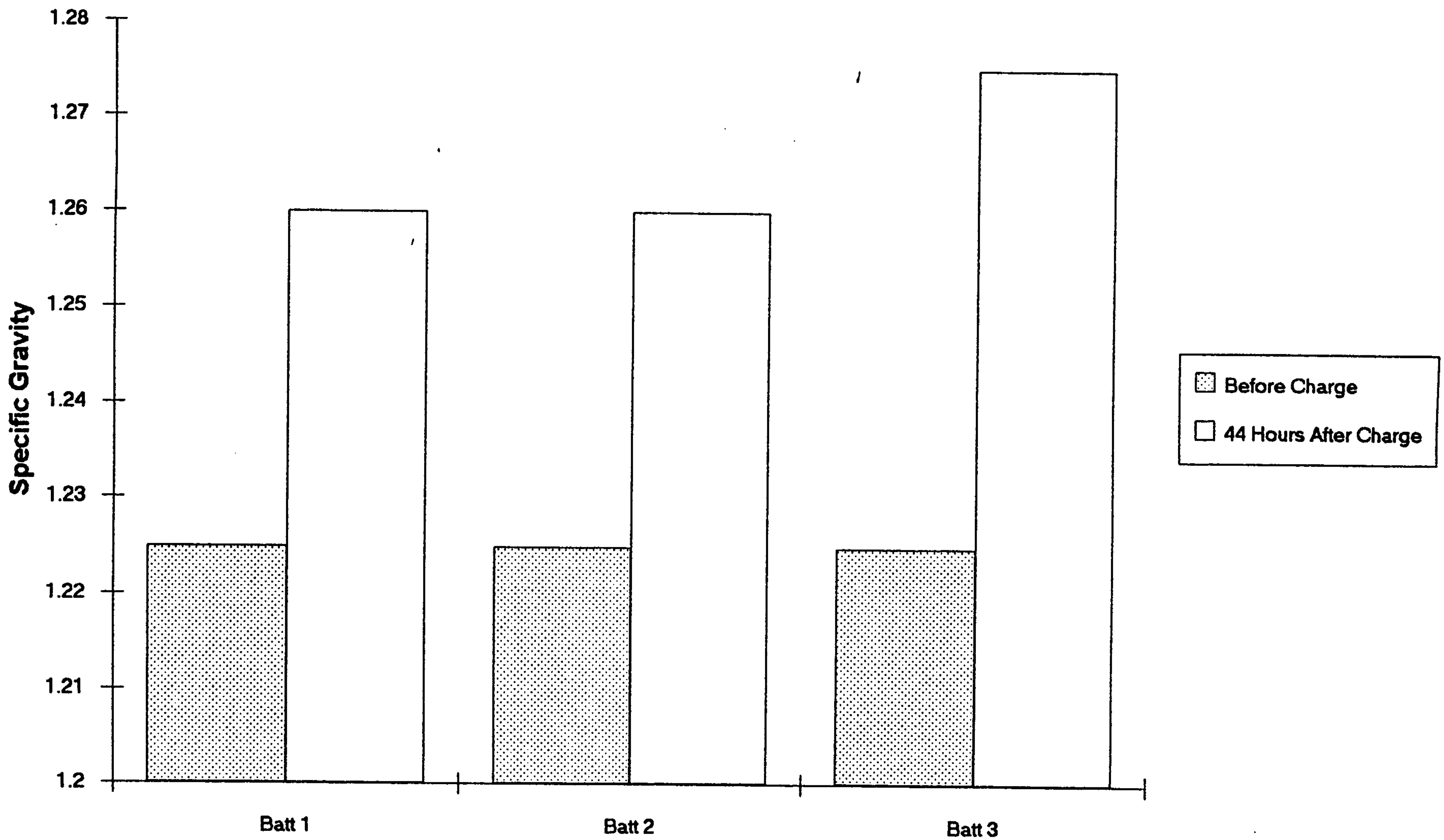
27 September, 1994

Neighborhood Electric Vehicle Product Test and Development Project

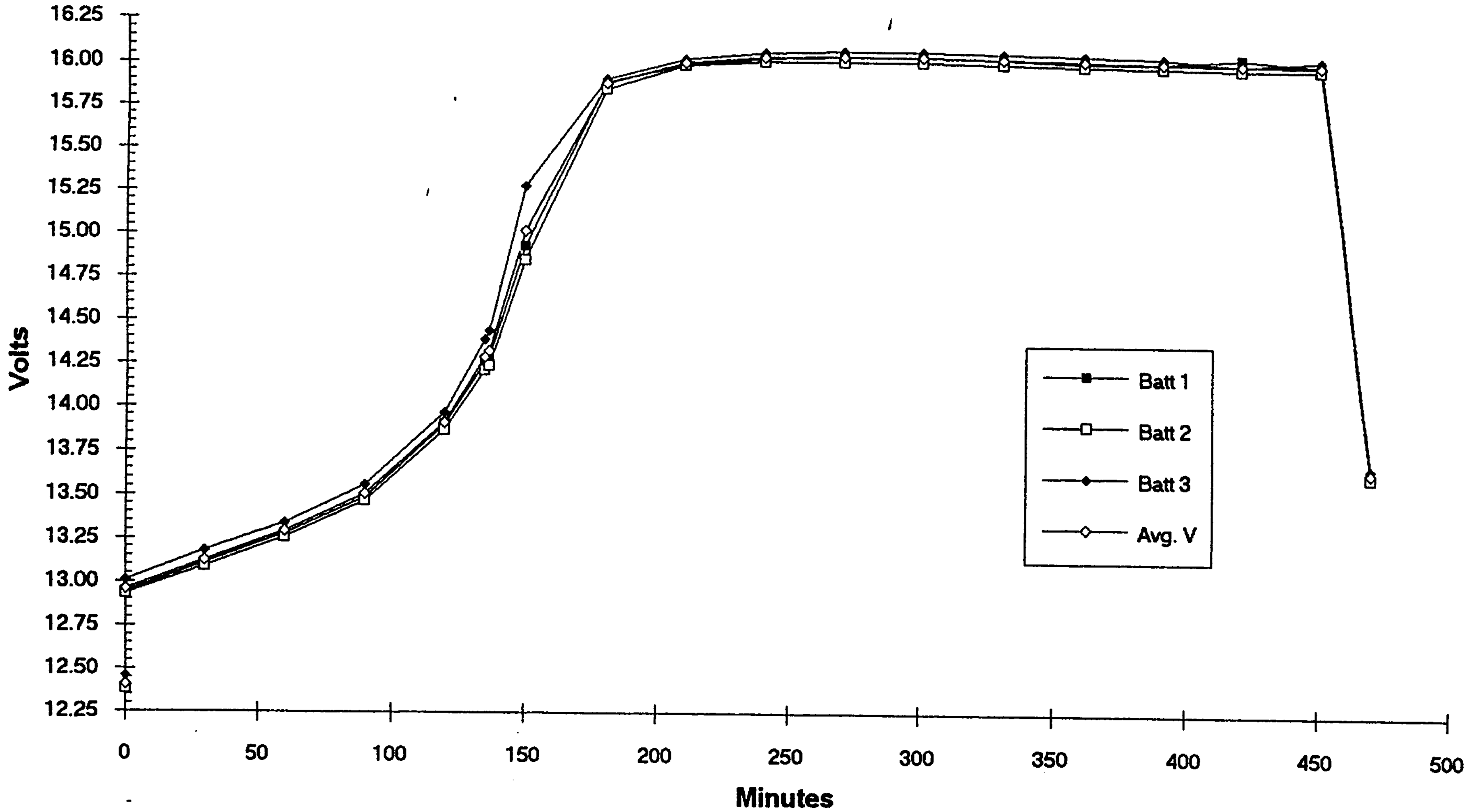
Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

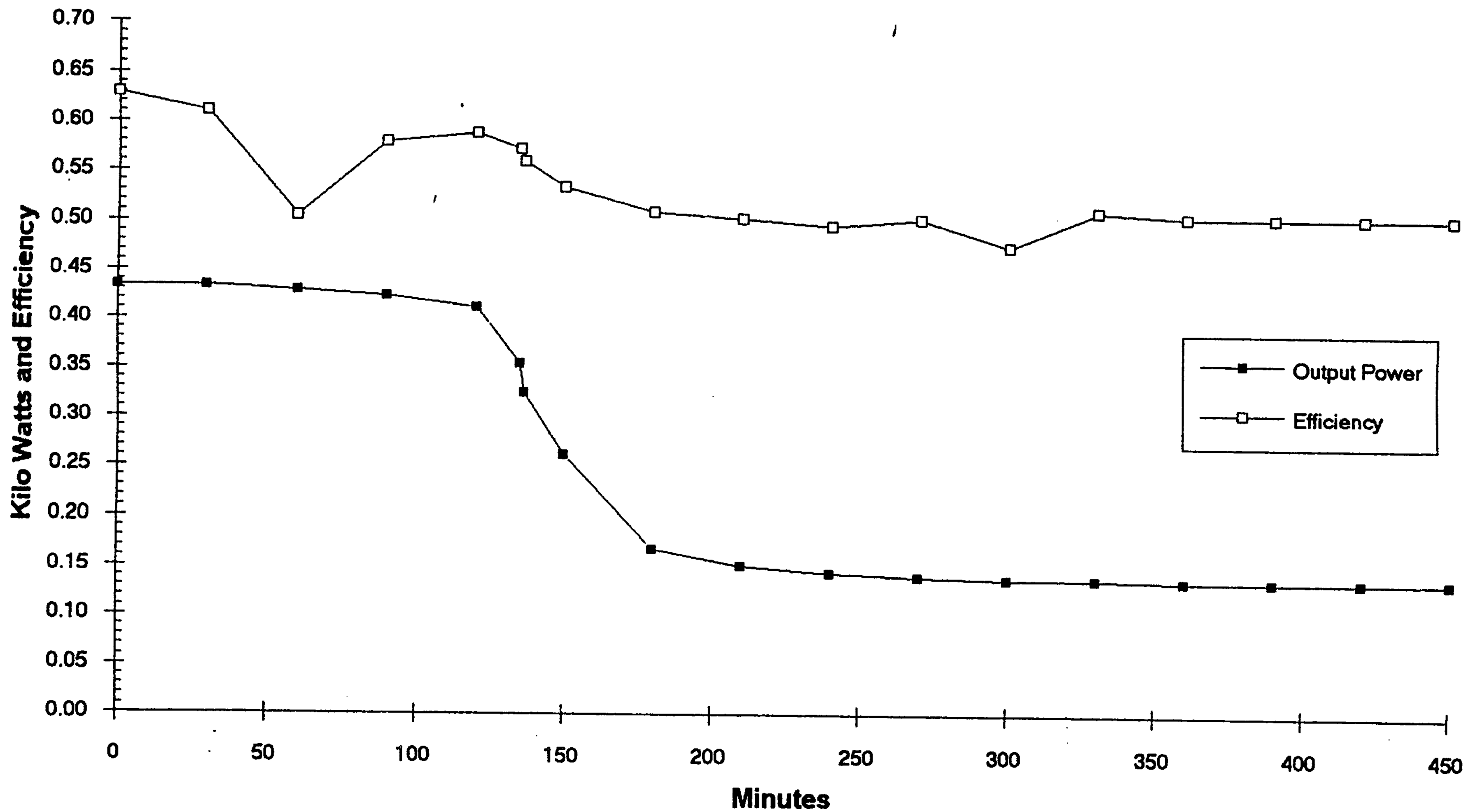
Specific Gravity for City-el 4135 Charged on 9-11-94



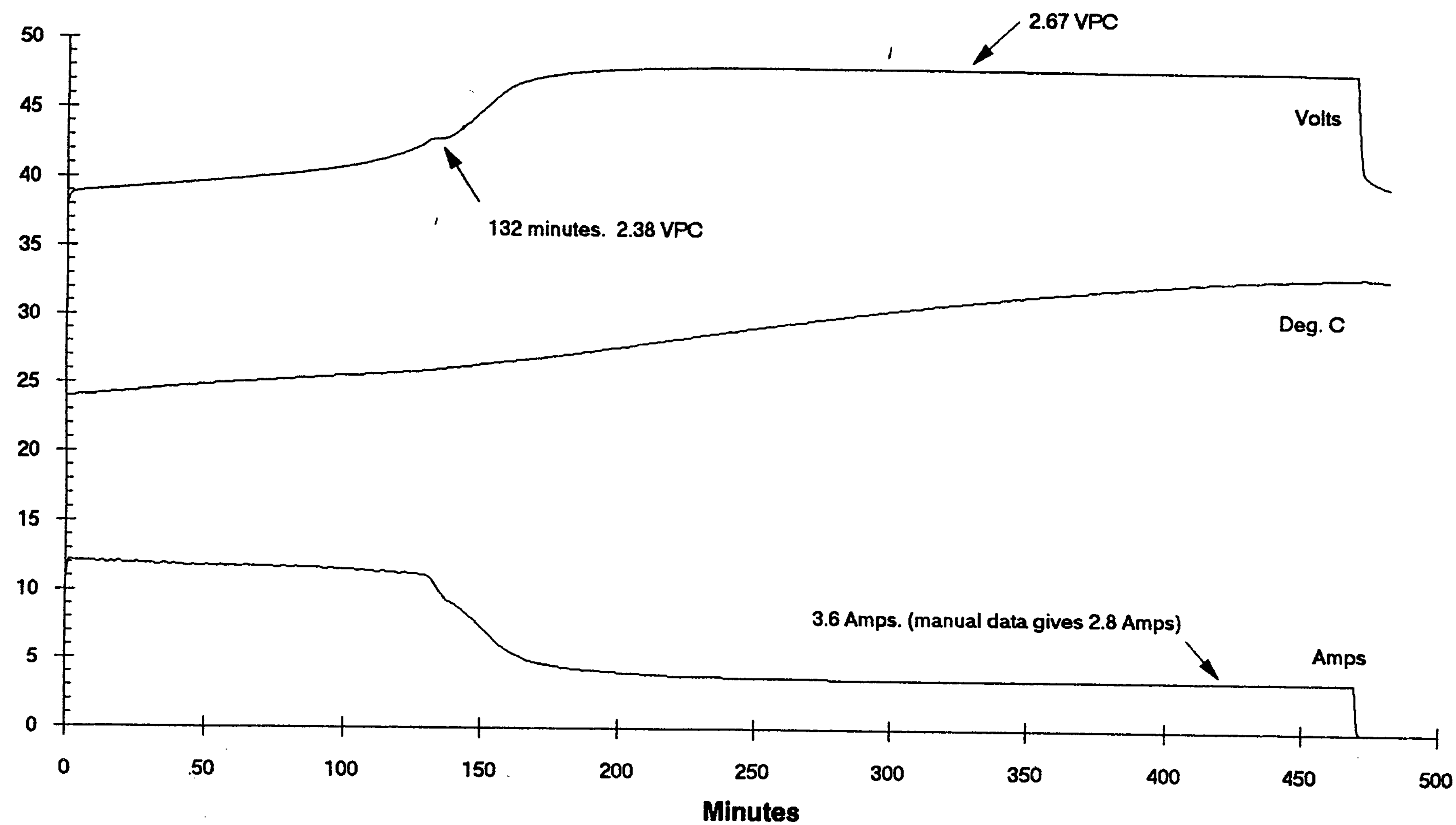
Voltage Variation of Batteries During Charge of City-el 4135 on 9-11-94



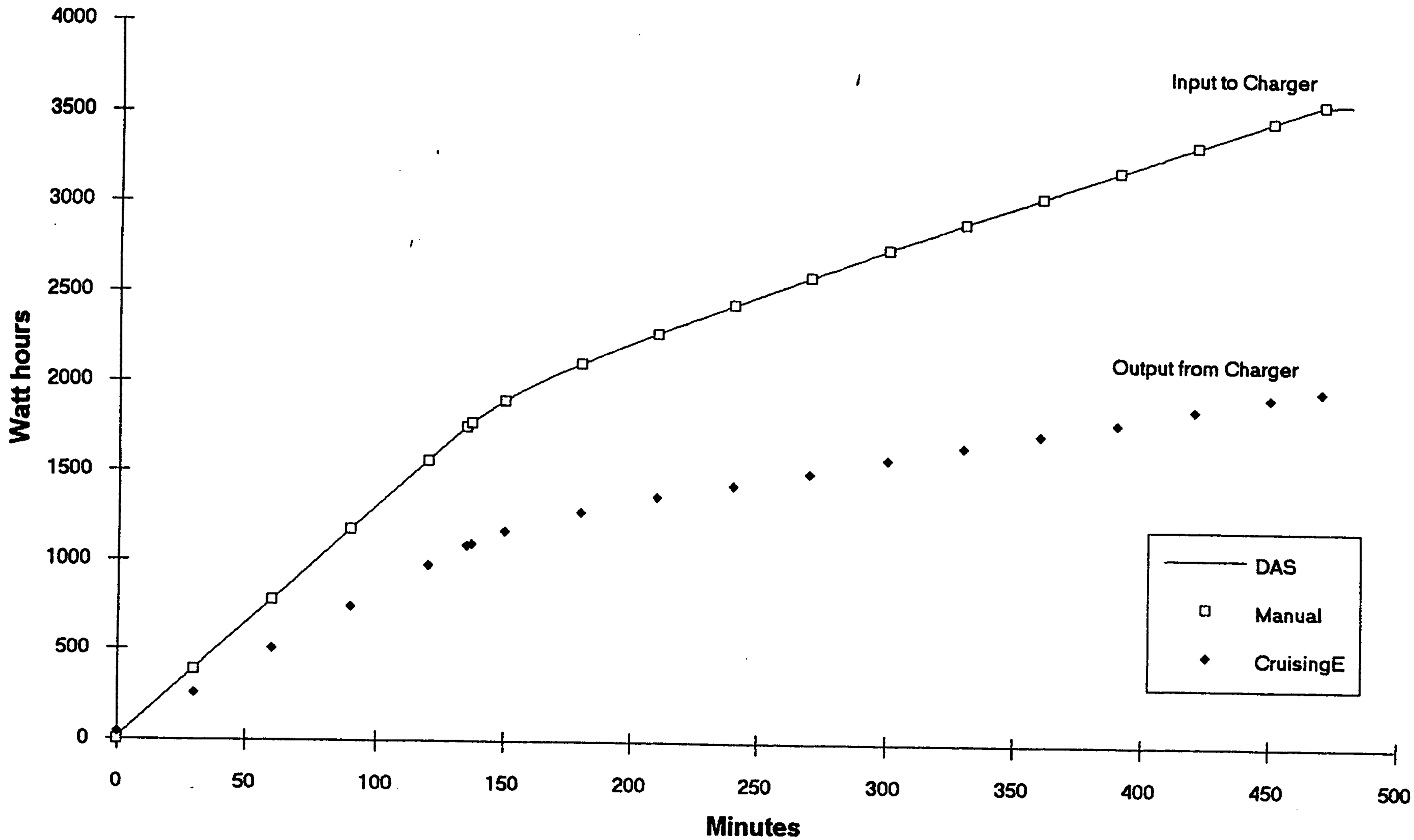
Charge Output Power and Efficiency for City-el 4135 on 9-11-94



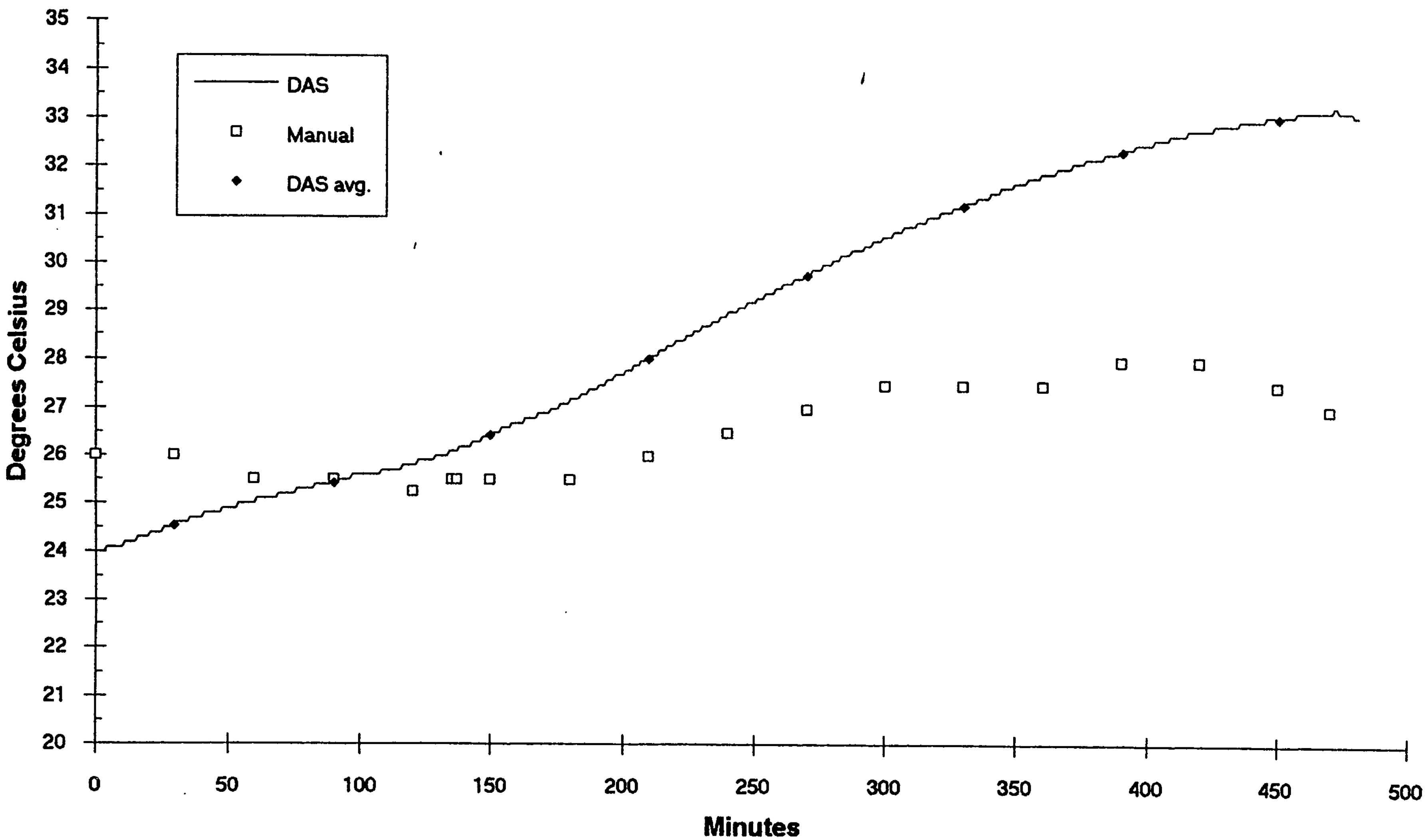
Charge Profiles for City-el 4135 as Recorded by the DAS on 9-11-94



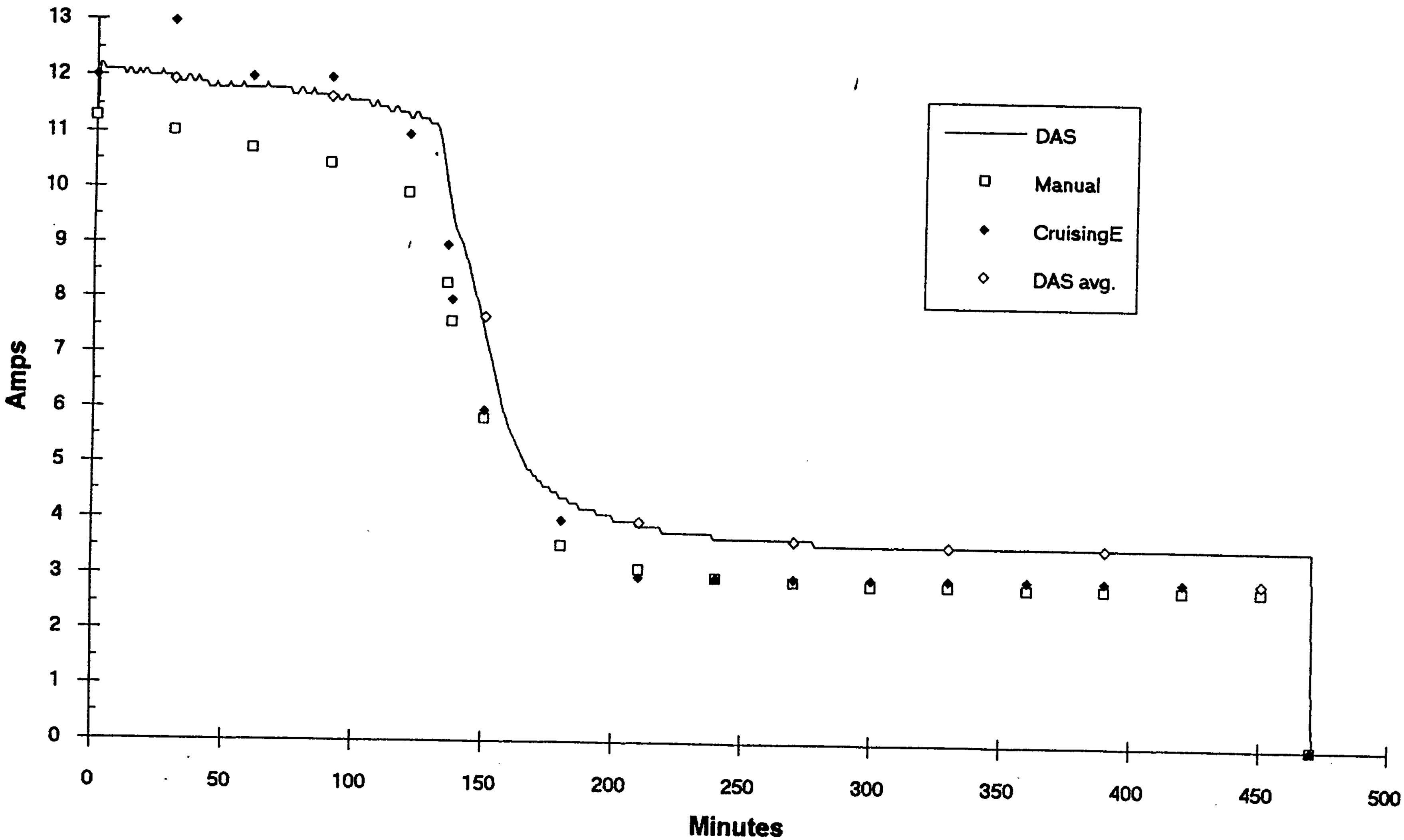
Charge Energy for City-el 4135 on 9-11-94



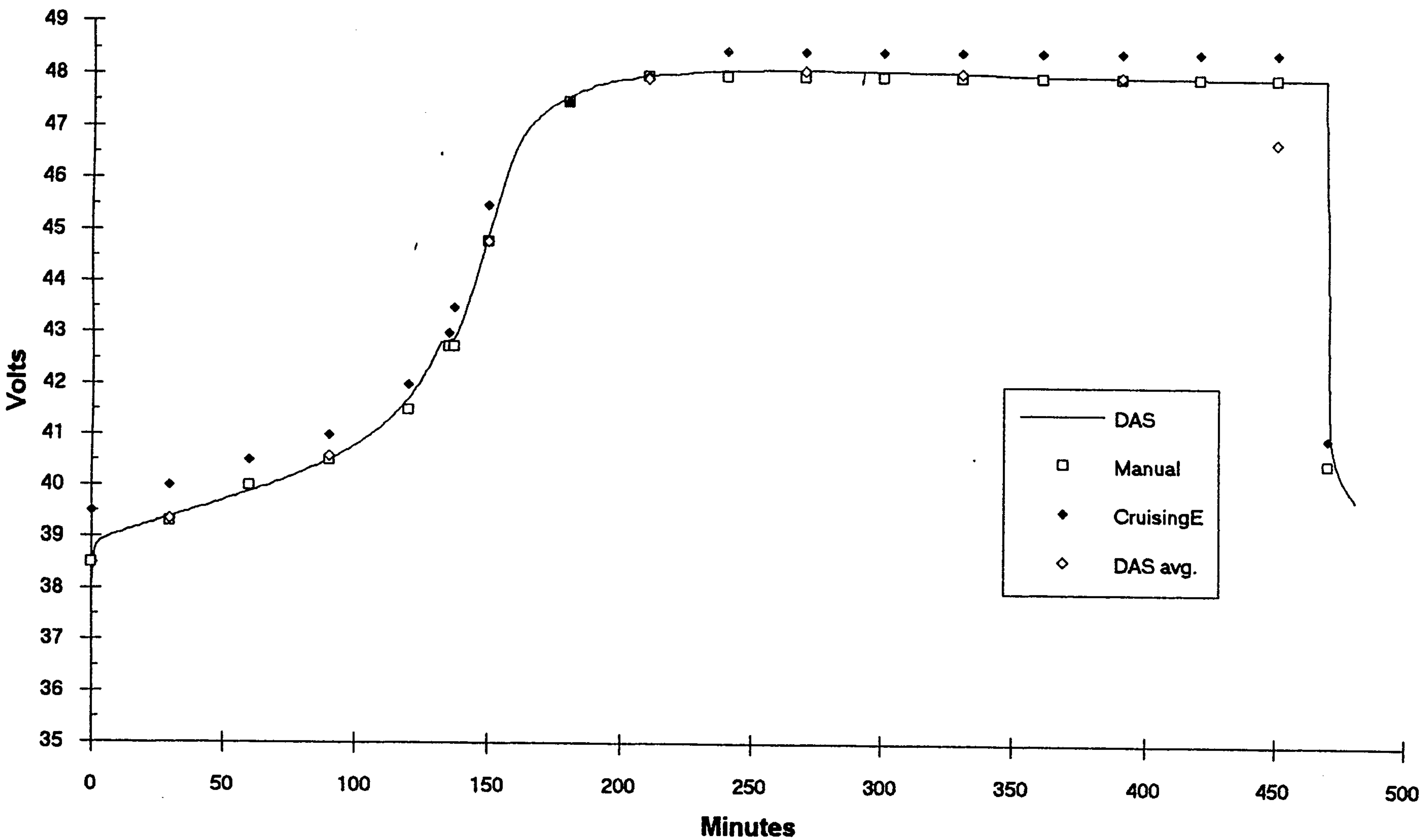
Charge Temperature for City-el 4135 on 9-11-94



Charge Current for City-el 4135 on 9-11-94



Charge Voltage for City-el 4135 on 9-11-94



City-el 4135 Charger Test on 9-11-94

Print Date: 9-29-94

	DAS Data				Manual Data				Cruising Equipment Data			DAS Hourly Average Data		
Minutes	Wh	Deg C	V	A	Wh	Deg C	V	A	Wh	V	A	Deg C	V	A
425	3370.5	32.9	48	3.6										
426	3375	32.9	48	3.6										
427	3380.4	32.9	48	3.6										
428	3384.9	32.9	48	3.6										
429	3390.3	32.9	48	3.6										
430	3394.8	32.9	48	3.6										
431	3399.3	32.9	48	3.6										
432	3404.7	32.9	48	3.6										
433	3409.2	32.9	48	3.6										
434	3414.6	32.9	48	3.6										
435	3419.1	33	48	3.6										
436	3424.5	33	48	3.6										
437	3429	33	48	3.6										
438	3433.5	33	48	3.6										
439	3438.9	33	48	3.6										
440	3443.4	33	48	3.6										
441	3448.8	33	48	3.6										
442	3453.3	33	48	3.6										
443	3457.8	33	48	3.6										
444	3463.2	33	48	3.6										
445	3467.7	33.1	48	3.6										
446	3473.1	33.1	48	3.6										
447	3477.6	33.1	48	3.6										
448	3482.1	33.1	48	3.6										
449	3487.5	33.1	48	3.6										
450	3492	33.1	47.99	3.6	3491.1	27.5	48.0	2.8	1950	48.5	3	33.06	46.77	3
451	3497.4	33.1	47.99	3.6										
452	3501.9	33.1	47.99	3.6										
453	3506.4	33.1	47.99	3.6										
454	3511.8	33.1	47.99	3.6										
455	3516.3	33.1	47.99	3.6										
456	3520.8	33.1	47.99	3.6										
457	3526.2	33.2	47.99	3.6										
458	3530.7	33.2	47.99	3.6										
459	3536.1	33.2	47.99	3.6										
460	3540.6	33.2	47.99	3.6										
461	3545.1	33.2	47.99	3.6										
462	3550.5	33.2	47.99	3.6										
463	3555	33.2	47.99	3.6										
464	3559.5	33.2	47.99	3.6										
465	3564.9	33.2	47.99	3.6										
466	3569.4	33.2	47.99	3.6										
467	3573.9	33.2	47.99	3.6										
468	3579.3	33.2	47.99	3.6										
469	3583.8	33.2	47.99	3.6										
470	3584.7	33.2	43.08	0.5	3583.8	27	40.5	0.0	1990	41.0	0			
471	3585.6	33.3	41.03	0										
472	3585.6	33.3	40.74	0										
473	3586.5	33.2	40.53	0										
474	3586.5	33.2	40.39	0										
475	3587.4	33.2	40.27	0										
476	3587.4	33.2	40.17	0										
477	3588.3	33.2	40.08	0										
478	3588.3	33.2	40	0										
479	3589.2	33.1	39.93	0										
480	3589.2	33.1	39.86	0										
481	3590.1	33.1	39.78	0										

DAS Data					Manual Data				Cruising Equipment Data			DAS Hourly Average Data		
Minutes	Wh	Deg C	V	A	Wh	Deg C	V	A	Wh	V	A	Deg C	V	A
353	3020.4	31.7	48.05	3.6										
354	3024.9	31.8	48.04	3.6										
355	3030.3	31.8	48.04	3.6										
356	3034.8	31.8	48.04	3.6										
357	3040.2	31.8	48.04	3.6										
358	3044.7	31.8	48.04	3.6										
359	3049.2	31.9	48.04	3.6										
360	3054.6	31.9	48.04	3.6	3053.7	27.5	48.0	2.8	1730	48.5	3			
361	3059.1	31.9	48.03	3.6										
362	3064.5	31.9	48.03	3.6										
363	3069	31.9	48.03	3.6										
364	3074.4	31.9	48.03	3.6										
365	3078.9	32	48.03	3.6										
366	3083.4	32	48.03	3.6										
367	3088.8	32	48.03	3.6										
368	3093.3	32	48.03	3.6										
369	3097.8	32	48.03	3.6										
370	3103.2	32	48.03	3.6										
371	3107.7	32.1	48.03	3.6										
372	3113.1	32.1	48.03	3.6										
373	3117.6	32.1	48.02	3.6										
374	3122.1	32.1	48.02	3.6										
375	3127.5	32.1	48.02	3.6										
376	3132	32.2	48.02	3.6										
377	3137.4	32.2	48.02	3.6										
378	3141.9	32.2	48.02	3.6										
379	3147.3	32.2	48.02	3.6										
380	3151.8	32.2	48.02	3.6										
381	3156.3	32.2	48.02	3.6										
382	3161.7	32.2	48.02	3.6										
383	3166.2	32.3	48.02	3.6										
384	3171.6	32.3	48.02	3.6										
385	3176.1	32.3	48.02	3.6										
386	3180.6	32.3	48.02	3.6										
387	3186	32.3	48.02	3.6										
388	3190.5	32.3	48.02	3.6										
389	3195.9	32.4	48.02	3.6										
390	3200.4	32.4	48.02	3.6	3199.5	28	48.0	2.8	1800	48.5	3	32.36	48.02	3.58
391	3204.9	32.4	48.01	3.6										
392	3210.3	32.4	48.01	3.6										
393	3214.8	32.4	48.01	3.6										
394	3220.2	32.4	48.01	3.6										
395	3224.7	32.5	48.01	3.6										
396	3230.1	32.5	48.01	3.6										
397	3234.6	32.5	48.01	3.6										
398	3239.1	32.5	48.01	3.6										
399	3244.5	32.5	48.01	3.6										
400	3249	32.5	48.01	3.6										
401	3254.4	32.5	48.01	3.6										
402	3258.9	32.6	48.01	3.6										
403	3263.4	32.6	48.01	3.6										
404	3268.8	32.6	48.01	3.6										
405	3273.3	32.6	48.01	3.6										
406	3277.8	32.6	48.01	3.6										
407	3283.2	32.6	48.01	3.6										
408	3287.7	32.7	48.01	3.6										
409	3293.1	32.7	48.01	3.6										
410	3297.6	32.7	48.01	3.6										
411	3302.1	32.7	48.01	3.6										
412	3307.5	32.7	48.01	3.6										
413	3312	32.7	48.01	3.6										
414	3317.4	32.7	48.01	3.6										
415	3321.9	32.8	48.01	3.6										
416	3326.4	32.8	48.01	3.6										
417	3331.8	32.8	48.01	3.6										
418	3336.3	32.8	48.01	3.6										
419	3341.7	32.8	48.01	3.6										
420	3346.2	32.8	48.01	3.6	3345.3	28	48.0	2.8	1880	48.5	3			
421	3350.7	32.8	48.01	3.6										
422	3356.1	32.8	48.01	3.6										
423	3360.6	32.8	48	3.6										
424	3366	32.8	48	3.6										

	DAS Data				Manual Data				Cruising Equipment Data			DAS Hourly Average Data		
Minutes	Wh	Deg C	V	A	Wh	Deg C	V	A	Wh	V	A	Deg C	V	A
281	2660.4	30.1	48.11	3.6										
282	2664.9	30.1	48.11	3.6										
283	2670.3	30.2	48.11	3.6										
284	2675.7	30.2	48.11	3.6										
285	2681.1	30.2	48.11	3.6										
286	2686.5	30.2	48.11	3.6										
287	2691	30.3	48.11	3.6										
288	2696.4	30.3	48.11	3.6										
289	2701.8	30.3	48.11	3.6										
290	2707.2	30.3	48.11	3.6										
291	2712.6	30.3	48.11	3.6										
292	2718	30.4	48.11	3.6										
293	2722.5	30.4	48.11	3.6										
294	2727.9	30.4	48.11	3.6										
295	2733.3	30.5	48.11	3.6										
296	2738.7	30.5	48.11	3.6										
297	2744.1	30.5	48.11	3.6										
298	2748.6	30.5	48.11	3.6										
299	2754	30.6	48.11	3.6										
300	2759.4	30.6	48.11	3.6	2758.5	27.5	48.0	2.9	1590	48.5	3			
301	2764.8	30.6	48.11	3.6										
302	2770.2	30.6	48.11	3.6										
303	2775.6	30.7	48.11	3.6										
304	2780.1	30.7	48.11	3.6										
305	2785.5	30.7	48.11	3.6										
306	2790.9	30.7	48.11	3.6										
307	2796.3	30.8	48.11	3.6										
308	2801.7	30.8	48.11	3.6										
309	2806.2	30.8	48.11	3.6										
310	2811.6	30.8	48.1	3.6										
311	2816.1	30.8	48.1	3.6										
312	2820.6	30.9	48.1	3.6										
313	2826	30.9	48.1	3.6										
314	2830.5	30.9	48.1	3.6										
315	2835.9	30.9	48.1	3.6										
316	2840.4	31	48.1	3.6										
317	2844.9	31	48.1	3.6										
318	2850.3	31	48.1	3.6										
319	2854.8	31	48.1	3.6										
320	2860.2	31	48.1	3.6										
321	2864.7	31.1	48.1	3.6										
322	2869.2	31.1	48.1	3.6										
323	2874.6	31.1	48.09	3.6										
324	2879.1	31.1	48.09	3.6										
325	2884.5	31.1	48.09	3.6										
326	2889	31.2	48.09	3.6										
327	2893.5	31.2	48.09	3.6										
328	2898.9	31.2	48.09	3.6										
329	2903.4	31.2	48.09	3.6										
330	2908.8	31.3	48.09	3.6	2907.0	27.5	48.0	2.9	1660	48.5	3	31.24	48.08	3.6
331	2913.3	31.3	48.09	3.6										
332	2917.8	31.3	48.08	3.6										
333	2923.2	31.3	48.08	3.6										
334	2927.7	31.3	48.08	3.6										
335	2933.1	31.4	48.08	3.6										
336	2937.6	31.4	48.08	3.6										
337	2942.1	31.4	48.07	3.6										
338	2947.5	31.4	48.07	3.6										
339	2952	31.4	48.07	3.6										
340	2957.4	31.5	48.07	3.6										
341	2961.9	31.5	48.07	3.6										
342	2966.4	31.5	48.07	3.6										
343	2971.8	31.5	48.06	3.6										
344	2976.3	31.6	48.06	3.6										
345	2981.7	31.6	48.06	3.6										
346	2986.2	31.6	48.06	3.6										
347	2991.6	31.6	48.06	3.6										
348	2996.1	31.6	48.05	3.6										
349	3000.6	31.7	48.05	3.6										
350	3006	31.7	48.05	3.6										
351	3010.5	31.7	48.05	3.6										
352	3015.9	31.7	48.05	3.6										

	DAS Data				Manual Data				Cruising Equipment Data			DAS Hourly Average Data		
Minutes	Wh	Deg C	V	A	Wh	Deg C	V	A	Wh	V	A	Deg C	V	A
209	2276.1	28	48	3.9										
210	2281.5	28	48.01	3.9	2279.7	26	48.0	3.2	1370	48.0	3	28.03	47.95	3.9
211	2286.9	28.1	48.01	3.9										
212	2292.3	28.1	48.01	3.9										
213	2297.7	28.1	48.01	3.9										
214	2303.1	28.2	48.02	3.9										
215	2309.4	28.2	48.02	3.9										
216	2314.8	28.2	48.02	3.9										
217	2320.2	28.3	48.02	3.9										
218	2325.6	28.3	48.03	3.9										
219	2331	28.3	48.03	3.8										
220	2336.4	28.4	48.03	3.8										
221	2341.8	28.4	48.03	3.8										
222	2347.2	28.4	48.04	3.8										
223	2352.6	28.4	48.04	3.8										
224	2358	28.5	48.05	3.8										
225	2363.4	28.5	48.06	3.8										
226	2368.8	28.5	48.06	3.8										
227	2374.2	28.6	48.07	3.8										
228	2379.6	28.6	48.08	3.8										
229	2385	28.6	48.08	3.8										
230	2390.4	28.7	48.08	3.8										
231	2395.8	28.7	48.09	3.8										
232	2401.2	28.7	48.09	3.8										
233	2406.6	28.7	48.1	3.8										
234	2412	28.8	48.1	3.8										
235	2417.4	28.8	48.1	3.8										
236	2422.8	28.8	48.1	3.8										
237	2428.2	28.9	48.1	3.8										
238	2433.6	28.9	48.11	3.8										
239	2439	28.9	48.11	3.7										
240	2444.4	29	48.11	3.7	2442.6	26.5	48.0	3.0	1440	48.5	3			
241	2449.8	29	48.11	3.7										
242	2455.2	29	48.11	3.7										
243	2460.6	29	48.11	3.7										
244	2466	29.1	48.11	3.7										
245	2470.5	29.1	48.11	3.7										
246	2475.9	29.1	48.11	3.7										
247	2481.3	29.2	48.11	3.7										
248	2486.7	29.2	48.11	3.7										
249	2492.1	29.2	48.11	3.7										
250	2497.5	29.2	48.11	3.7										
251	2502.9	29.3	48.11	3.7										
252	2508.3	29.3	48.11	3.7										
253	2513.7	29.3	48.11	3.7										
254	2518.2	29.4	48.12	3.7										
255	2523.6	29.4	48.12	3.7										
256	2529	29.4	48.12	3.7										
257	2534.4	29.4	48.12	3.7										
258	2539.8	29.5	48.12	3.7										
259	2545.2	29.5	48.12	3.7										
260	2550.6	29.5	48.12	3.7										
261	2556	29.6	48.12	3.7										
262	2560.5	29.6	48.12	3.7										
263	2565.9	29.6	48.12	3.7										
264	2571.3	29.6	48.12	3.7										
265	2576.7	29.7	48.12	3.7										
266	2582.1	29.7	48.12	3.7										
267	2586.6	29.7	48.12	3.7										
268	2592	29.7	48.12	3.7										
269	2597.4	29.8	48.12	3.7										
270	2602.8	29.8	48.12	3.7	2601.0	27	48.0	2.9	1510	48.5	3	29.77	48.11	3.67
271	2608.2	29.8	48.12	3.7										
272	2612.7	29.9	48.12	3.7										
273	2618.1	29.9	48.12	3.7										
274	2623.5	29.9	48.12	3.7										
275	2628.9	29.9	48.12	3.7										
276	2634.3	30	48.12	3.7										
277	2638.8	30	48.12	3.7										
278	2644.2	30	48.12	3.6										
279	2649.6	30	48.12	3.6										
280	2655	30.1	48.12	3.6										

	DAS Data				Manual Data				Cruising Equipment Data			DAS Hourly Average Data		
Minutes	Wh	Deg C	V	A	Wh	Deg C	V	A	Wh	V	A	Deg C	V	A
137	1776.6	26.1	42.89	9.5	1773.0	25.5	42.8	7.6	1100	43.5	8			
138	1786.5	26.2	42.97	9.3										
139	1797.3	26.2	43.1	9.2										
140	1807.2	26.2	43.23	9.1										
141	1817.1	26.2	43.38	9										
142	1827	26.2	43.54	8.8										
143	1836.9	26.3	43.7	8.7										
144	1846.8	26.3	43.86	8.5										
145	1856.7	26.3	44.02	8.3										
146	1865.7	26.3	44.2	8.1										
147	1874.7	26.4	44.38	8										
148	1883.7	26.4	44.56	7.8										
149	1892.7	26.4	44.74	7.6										
150	1901.7	26.5	44.9	7.4	1899.0	25.5	44.8	5.8	1170	45.5	6	26.44	44.81	7.7
151	1910.7	26.5	45.08	7.2										
152	1918.8	26.5	45.28	7										
153	1926.9	26.5	45.46	6.8										
154	1935	26.6	45.64	6.6										
155	1943.1	26.6	45.8	6.4										
156	1950.3	26.6	45.97	6.2										
157	1958.4	26.6	46.13	6										
158	1965.6	26.7	46.28	5.9										
159	1972.8	26.7	46.42	5.7										
160	1980	26.7	46.55	5.6										
161	1987.2	26.7	46.66	5.5										
162	1994.4	26.7	46.76	5.4										
163	2000.7	26.8	46.85	5.3										
164	2007.9	26.8	46.92	5.2										
165	2014.2	26.8	46.99	5.1										
166	2020.5	26.8	47.05	5										
167	2027.7	26.8	47.11	4.9										
168	2034	26.9	47.15	4.9										
169	2040.3	26.9	47.21	4.8										
170	2046.6	26.9	47.25	4.8										
171	2052.9	26.9	47.3	4.7										
172	2059.2	26.9	47.33	4.7										
173	2065.5	27	47.38	4.6										
174	2071.8	27	47.41	4.6										
175	2078.1	27	47.44	4.6										
176	2084.4	27.1	47.48	4.5										
177	2090.7	27.1	47.51	4.5										
178	2097	27.1	47.53	4.5										
179	2102.4	27.1	47.56	4.4										
180	2108.7	27.2	47.6	4.4	2106.9	25.5	47.5	3.5	1280	47.5	4			
181	2115	27.2	47.62	4.4										
182	2120.4	27.2	47.63	4.4										
183	2126.7	27.2	47.67	4.3										
184	2133	27.3	47.7	4.3										
185	2138.4	27.3	47.71	4.3										
186	2144.7	27.3	47.72	4.3										
187	2150.1	27.4	47.73	4.2										
188	2156.4	27.4	47.75	4.2										
189	2162.7	27.4	47.79	4.2										
190	2168.1	27.4	47.81	4.2										
191	2174.4	27.5	47.82	4.2										
192	2179.8	27.5	47.82	4.2										
193	2185.2	27.5	47.84	4.2										
194	2191.5	27.6	47.85	4.1										
195	2196.9	27.6	47.87	4.1										
196	2203.2	27.6	47.89	4.1										
197	2208.6	27.7	47.9	4.1										
198	2214	27.7	47.91	4.1										
199	2220.3	27.7	47.91	4.1										
200	2225.7	27.7	47.92	4										
201	2231.1	27.8	47.92	4										
202	2236.5	27.8	47.93	4										
203	2242.8	27.8	47.93	4										
204	2248.2	27.9	47.94	4										
205	2253.6	27.9	47.96	4										
206	2259	27.9	47.97	4										
207	2264.4	28	47.98	4										
208	2270.7	28	47.99	4										

	DAS Data				Manual Data				Cruising Equipment Data			DAS Hourly Average Data		
Minutes	Wh	Deg C	V	A	Wh	Deg C	V	A	Wh	V	A	Deg C	V	A
65	849.6	25.1	39.98	11.9										
66	863.1	25.1	39.99	11.8										
67	875.7	25.1	40	11.8										
68	889.2	25.1	40.02	11.8										
69	902.7	25.2	40.05	11.8										
70	915.3	25.2	40.08	11.8										
71	928.8	25.2	40.09	11.8										
72	942.3	25.2	40.1	11.8										
73	954.9	25.2	40.12	11.8										
74	968.4	25.2	40.15	11.8										
75	981	25.2	40.17	11.7										
76	994.5	25.3	40.18	11.7										
77	1008	25.3	40.2	11.7										
78	1020.6	25.3	40.23	11.8										
79	1034.1	25.3	40.25	11.8										
80	1047.6	25.3	40.27	11.7										
81	1060.2	25.3	40.29	11.7										
82	1073.7	25.3	40.31	11.7										
83	1087.2	25.4	40.34	11.8										
84	1099.8	25.4	40.36	11.7										
85	1113.3	25.4	40.38	11.7										
86	1125.9	25.4	40.4	11.7										
87	1139.4	25.4	40.43	11.7										
88	1152.9	25.4	40.46	11.7										
89	1165.5	25.4	40.48	11.7										
90	1179	25.5	40.5	11.7	1175.4	25.5	40.5	10.5	750	41.0	12	25.43	40.58	11.66
91	1191.6	25.5	40.53	11.7										
92	1205.1	25.5	40.56	11.7										
93	1218.6	25.5	40.58	11.6										
94	1231.2	25.5	40.61	11.6										
95	1244.7	25.5	40.64	11.7										
96	1257.3	25.5	40.68	11.7										
97	1270.8	25.6	40.69	11.6										
98	1283.4	25.6	40.71	11.6										
99	1296.9	25.6	40.76	11.6										
100	1309.5	25.6	40.79	11.6										
101	1323	25.6	40.81	11.6										
102	1335.6	25.6	40.85	11.6										
103	1348.2	25.6	40.9	11.6										
104	1361.7	25.6	40.93	11.6										
105	1374.3	25.6	40.96	11.5										
106	1386.9	25.6	41	11.5										
107	1400.4	25.6	41.05	11.6										
108	1413	25.7	41.1	11.5										
109	1425.6	25.7	41.12	11.5										
110	1439.1	25.7	41.17	11.5										
111	1451.7	25.7	41.23	11.5										
112	1464.3	25.7	41.27	11.4										
113	1476.9	25.7	41.31	11.4										
114	1490.4	25.7	41.36	11.5										
115	1503	25.7	41.43	11.5										
116	1515.6	25.8	41.48	11.4										
117	1529.1	25.8	41.53	11.4										
118	1541.7	25.8	41.59	11.4										
119	1554.3	25.8	41.66	11.4										
120	1566.9	25.8	41.71	11.3	1563.3	25.25	41.5	9.9	980	42.0	11			
121	1579.5	25.8	41.77	11.3										
122	1593	25.9	41.86	11.4										
123	1605.6	25.9	41.94	11.4										
124	1618.2	25.9	42	11.3										
125	1631.7	25.9	42.08	11.3										
126	1644.3	25.9	42.19	11.3										
127	1656.9	25.9	42.28	11.3										
128	1669.5	25.9	42.35	11.2										
129	1682.1	26	42.47	11.2										
130	1694.7	26	42.61	11.2										
131	1707.3	26	42.73	11.1										
132	1719.9	26	42.82	10.9										
133	1731.6	26	42.83	10.6										
134	1743.3	26.1	42.84	10.3										
135	1755	26.1	42.85	10	1751.4	25.5	42.8	8.3	1090	43.0	9			
136	1765.8	26.1	42.87	9.8										

City-el 4135 Charger Test

Date: 9-11-94

	DAS Data				Manual Data				Cruising Equipment Data			DAS Hourly Average Data		
Minutes	Wh DAS	Deg C DAS	V DAS	A DAS	Wh Manual	Deg C Manual	V Manual	A Manual	Wh CruisingE	V CruisingE	A CruisingE	Deg C DAS avg.	V DAS avg.	A DAS avg.
0	11.7	24	38.06	11	0.0	26	38.5	11.3	40	39.5	12			
1	24.3	24	38.69	12.2										
2	36.9	24	38.84	12.2										
3	49.5	24	38.9	12.1										
4	62.1	24.1	38.94	12.1										
5	74.7	24.1	38.96	12.1										
6	87.3	24.1	38.98	12.1										
7	99.9	24.1	39.01	12.1										
8	112.5	24.1	39.03	12.1										
9	125.1	24.1	39.04	12.1										
10	137.7	24.1	39.06	12.1										
11	150.3	24.2	39.07	12										
12	163.8	24.2	39.09	12.1										
13	176.4	24.2	39.11	12.1										
14	189	24.2	39.13	12										
15	201.6	24.2	39.14	12										
16	214.2	24.3	39.16	12.1										
17	227.7	24.3	39.18	12										
18	240.3	24.3	39.19	12.1										
19	252.9	24.3	39.22	12.1										
20	266.4	24.3	39.23	12										
21	279	24.4	39.24	12										
22	291.6	24.4	39.26	12										
23	305.1	24.4	39.27	12										
24	317.7	24.4	39.29	12										
25	330.3	24.4	39.31	12.1										
26	342.9	24.5	39.32	12										
27	356.4	24.5	39.34	12										
28	369	24.5	39.36	12										
29	381.6	24.5	39.37	12										
30	395.1	24.5	39.39	12	390.6	26	39.3	11.0	260	40.0	13	24.53	39.35	11.94
31	407.7	24.6	39.4	12										
32	420.3	24.6	39.41	11.9										
33	432.9	24.6	39.43	11.9										
34	446.4	24.6	39.45	11.9										
35	459	24.6	39.47	12										
36	471.6	24.7	39.49	12										
37	485.1	24.7	39.49	11.9										
38	497.7	24.7	39.51	11.9										
39	510.3	24.7	39.54	12										
40	522.9	24.7	39.55	11.9										
41	536.4	24.8	39.57	11.9										
42	549	24.8	39.58	11.9										
43	561.6	24.8	39.59	11.8										
44	574.2	24.8	39.6	11.8										
45	586.8	24.8	39.61	11.8										
46	600.3	24.8	39.64	11.9										
47	612.9	24.8	39.66	11.8										
48	626.4	24.9	39.67	11.8										
49	639	24.9	39.69	11.8										
50	652.5	24.9	39.7	11.8										
51	665.1	24.9	39.73	11.9										
52	678.6	24.9	39.75	11.8										
53	692.1	24.9	39.76	11.8										
54	704.7	25	39.78	11.8										
55	718.2	25	39.79	11.8										
56	730.8	25	39.81	11.9										
57	744.3	25	39.83	11.8										
58	757.8	25	39.85	11.8										
59	770.4	25	39.87	11.8										
60	783.9	25	39.89	11.8	780.3	25.5	40.0	10.7	510	40.5	12			
61	797.4	25.1	39.9	11.8										
62	810	25.1	39.91	11.8										
63	823.5	25.1	39.93	11.8										
64	836.1	25.1	39.96	11.8										

Cruising Equipment Meter				Specific Gravity			Data Analysis									
Amps	Volts	kWh read	KWH	Batt 1	Batt 2	Batt 3	Sum of V	Difference	Avg. V	Stdev. V	Max Diff.	DC Power	Charge eff.	W-h used	Man. Wh	% Diff.
0	38.0	-0.85	0.00	1.225	1.225	1.225	37.22	-0.22	12.41	0.046	0.08	0.00				
12	39.5	-0.81	0.04				38.88	-0.38	12.96	0.044	0.08	0.43	63%	0.0		
13	40.0	-0.59	0.26				39.38	-0.08	13.13	0.047	0.09	0.43	61%	390.6	216.7	17%
12	40.5	-0.34	0.51				39.88	0.12	13.29	0.042	0.08	0.43	50%	389.7	431.3	15%
12	41.0	-0.10	0.75				40.52	-0.02	13.51	0.047	0.09	0.42	58%	395.1	643.0	14%
11	42.0	0.13	0.98				41.74	-0.24	13.91	0.051	0.10	0.41	59%	387.9	849.2	13%
9	43.0	0.24	1.09				42.86	-0.11	14.29	0.093	0.18	0.35	57%	188.1	938.0	14%
8	43.5	0.25	1.10				42.97	-0.22	14.32	0.104	0.20	0.33	56%	21.6	946.1	14%
6	45.5	0.32	1.17				45.06	-0.26	15.02	0.229	0.43	0.26	53%	126.0	1005.1	14%
4	47.5	0.43	1.28				47.65	-0.15	15.88	0.031	0.06	0.17	51%	207.9	1089.3	15%
3	48.0	0.52	1.37				48.02	-0.02	16.01	0.021	0.04	0.15	50%	172.8	1164.9	15%
3	48.5	0.59	1.44				48.13	-0.13	16.04	0.025	0.05	0.14	50%	162.9	1236.9	14%
3	48.5	0.66	1.51				48.15	-0.15	16.05	0.030	0.06	0.14	50%	158.4	1307.4	13%
3	48.5	0.74	1.59				48.15	-0.15	16.05	0.030	0.06	0.14	48%	157.5	1376.5	13%
3	48.5	0.81	1.66				48.12	-0.12	16.04	0.030	0.06	0.14	51%	148.5	1445.6	13%
3	48.5	0.88	1.73				48.08	-0.08	16.03	0.031	0.06	0.14	51%	146.7	1514.0	12%
3	48.5	0.95	1.80				48.06	-0.06	16.02	0.030	0.06	0.14	51%	145.8	1582.4	12%
3	48.5	1.03	1.88				48.04	-0.04	16.01	0.035	0.07	0.14	51%	145.8	1650.7	12%
3	48.5	1.10	1.95				48.03	-0.03	16.01	0.030	0.06	0.14	51%	145.8	1719.1	12%
0	41.0	1.14	1.99				40.97	-0.47	13.66	0.025	0.05	0.00		92.7		
				1.26	1.26	1.275	37.65	-0.05	12.55	0.053	0.10	0.00		0.0		
												Average:	53%		Average:	14%

<---- Continued

City-el 4135 Charger and Battery Test

Date: 9-11-94

Manual Data

Date	Time	Minutes	Pack V	kilo Watts	W-h read	Watt hour	Line V	Shunt mV	Amps	Temp. C	Batt 1	bubble?	Batt 2	bubble?	Batt 3	bubble?
9-11-94	11:55	0	37.0	0.00	321424	0.0	0	0	0.0	26	12.38		12.38		12.46	
9-11-94	12:00	0	38.5	0.69	321424	0.0	116	37.2	11.3	26	12.94		12.93		13.01	
9-11-94	12:30	30	39.3	0.71	321858	390.6	117	36.4	11.0	26	13.11		13.09		13.18	
9-11-94	13:00	60	40.0	0.85	322291	780.3	117	35.4	10.7	25.5	13.28		13.26		13.34	
9-11-94	13:30	90	40.5	0.73	322730	1175.4	117	34.5	10.5	25.5	13.49		13.47		13.56	
9-11-94	14:00	120	41.5	0.70	323161	1563.3	116	32.8	9.9	25.25	13.90	barely	13.87	barely	13.97	barely
9-11-94	14:15	135	42.8	0.62	323370	1751.4	117	27.4	8.3	25.5	14.26	slightly	14.21	slightly	14.39	slightly
9-11-94	14:16:30	136.5	42.8	0.58	323394	1773.0	117	25.1	7.6	25.5	14.29	82% on	14.24	82% on	14.44	82% on
9-11-94	14:30	150	44.8	0.49	323534	1899.0	118	19.3	5.8	25.5	14.93	yes	14.85	slightly	15.28	yes
9-11-94	15:00	180	47.5	0.33	323765	2106.9	118	11.7	3.5	25.5	15.89	yes	15.85	yes	15.91	yes
9-11-94	15:30	210	48.0	0.30	323957	2279.7	120	10.4	3.2	26	16.00	yes	15.99	yes	16.03	yes
9-11-94	16:00	240	48.0	0.29	324138	2442.6	120	9.9	3.0	26.5	16.04	yes	16.02	yes	16.07	yes
9-11-94	16:30	270	48.0	0.28	324314	2601.0	118	9.7	2.9	27	16.05	yes	16.02	yes	16.08	yes
9-11-94	17:00	300	48.0	0.29	324489	2758.5	120	9.5	2.9	27.5	16.05	yes	16.02	yes	16.08	yes
9-11-94	17:30	330	48.0	0.27	324654	2907.0	120	9.5	2.9	27.5	16.04	yes	16.01	yes	16.07	yes
9-11-94	18:00	360	48.0	0.27	324817	3053.7	121	9.4	2.8	27.5	16.02	yes	16.00	yes	16.06	yes
9-11-94	18:30	390	48.0	0.27	324979	3199.5	121	9.4	2.8	28	16.02	yes	15.99	yes	16.05	yes
9-11-94	19:00	420	48.0	0.27	325141	3345.3	121	9.4	2.8	28	16.05	yes	15.98	yes	16.01	yes
9-11-94	19:30	450	48.0	0.27	325303	3491.1	121	9.4	2.8	27.5	16.01	yes	15.98	yes	16.04	yes
9-11-94	19:50	470	40.5	0.03	325406	3583.8	121	-0.1	0.0	27	13.66		13.63		13.68	
9-13-94	16:21	3081	37.6	0.00	325406	3583.8	0	0	0.0	33	12.53		12.51		12.61	

Continued ---->

Pacific EV | 4135 Charge Test | Lance → Atkins

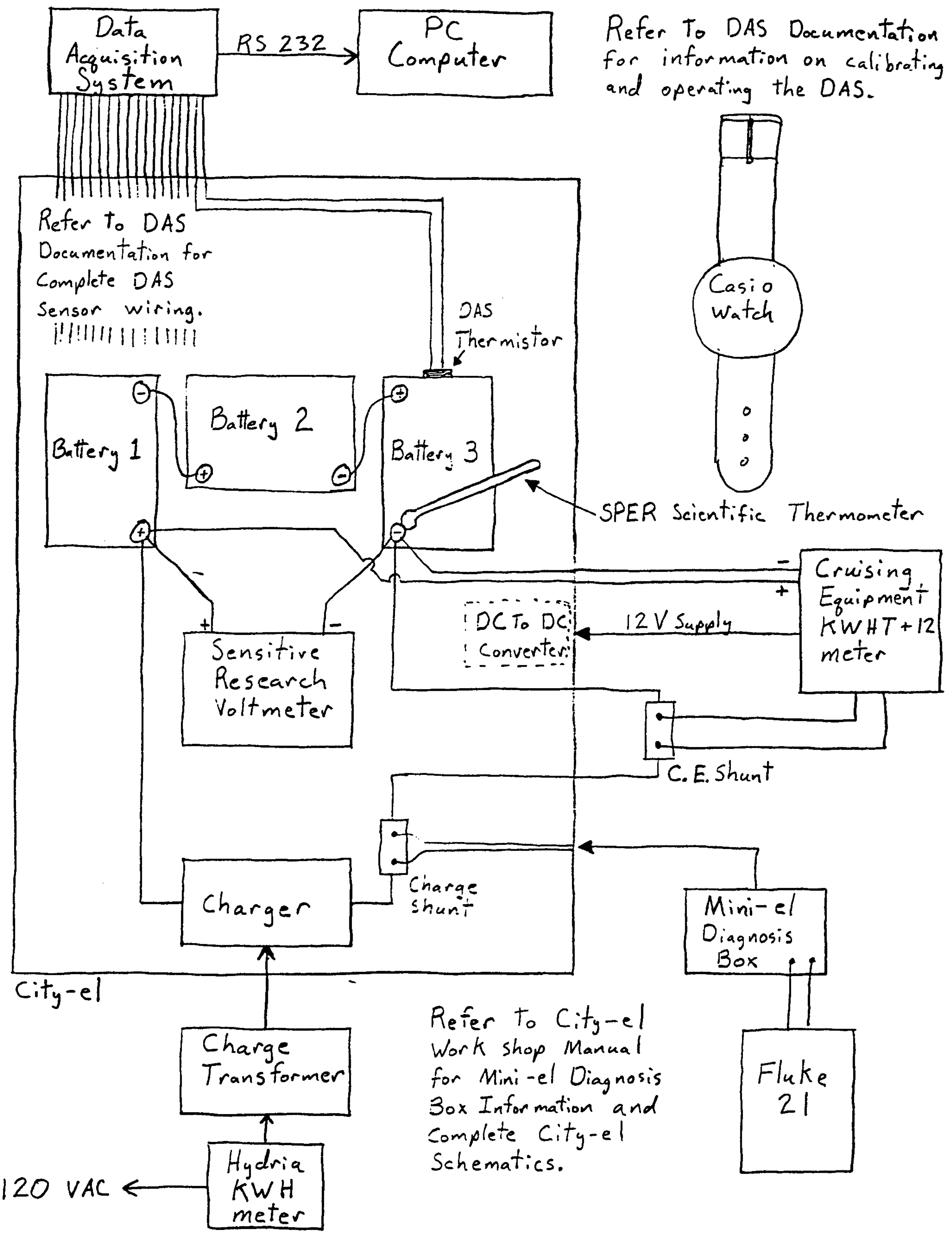
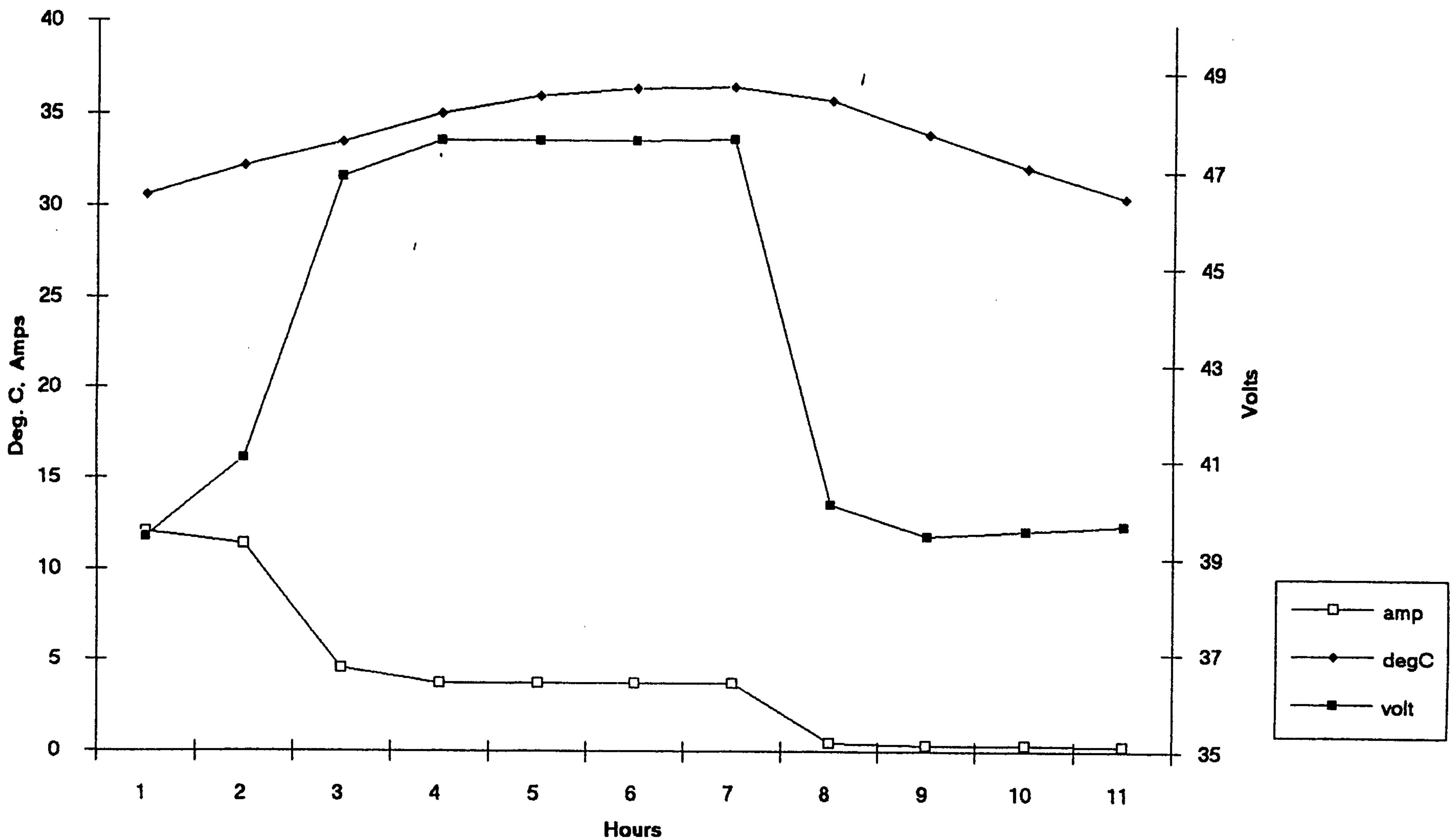


Figure 1: City-el 4135 Charger and Battery Test Setup.

Date: 9-9-94 4:02 PM

VIN: 4135

City-el Charge Profile



City-el DAS Charge Data

VIN#: 4135
Date: 9-9-94
Time: 4:02 PM

hour	AC W	volt	amp	degC	DC kWh
1	808	39.4	12.02	30.64	0.47
2	788	41.04	11.38	32.2	0.94
3	377	46.88	4.56	33.54	1.15
4	321	47.61	3.71	35.08	1.33
5	320	47.61	3.68	36.02	1.51
6	301	47.61	3.68	36.43	1.68
7	293	47.64	3.69	36.53	1.86
8	63	40.09	0.46	35.85	1.88
9	55	39.43	0.32	34.02	1.89
10	54	39.54	0.3	32.19	1.90
11	53	39.64	0.29	30.51	1.91
12	58	92.06	0.35	57.63	1.94

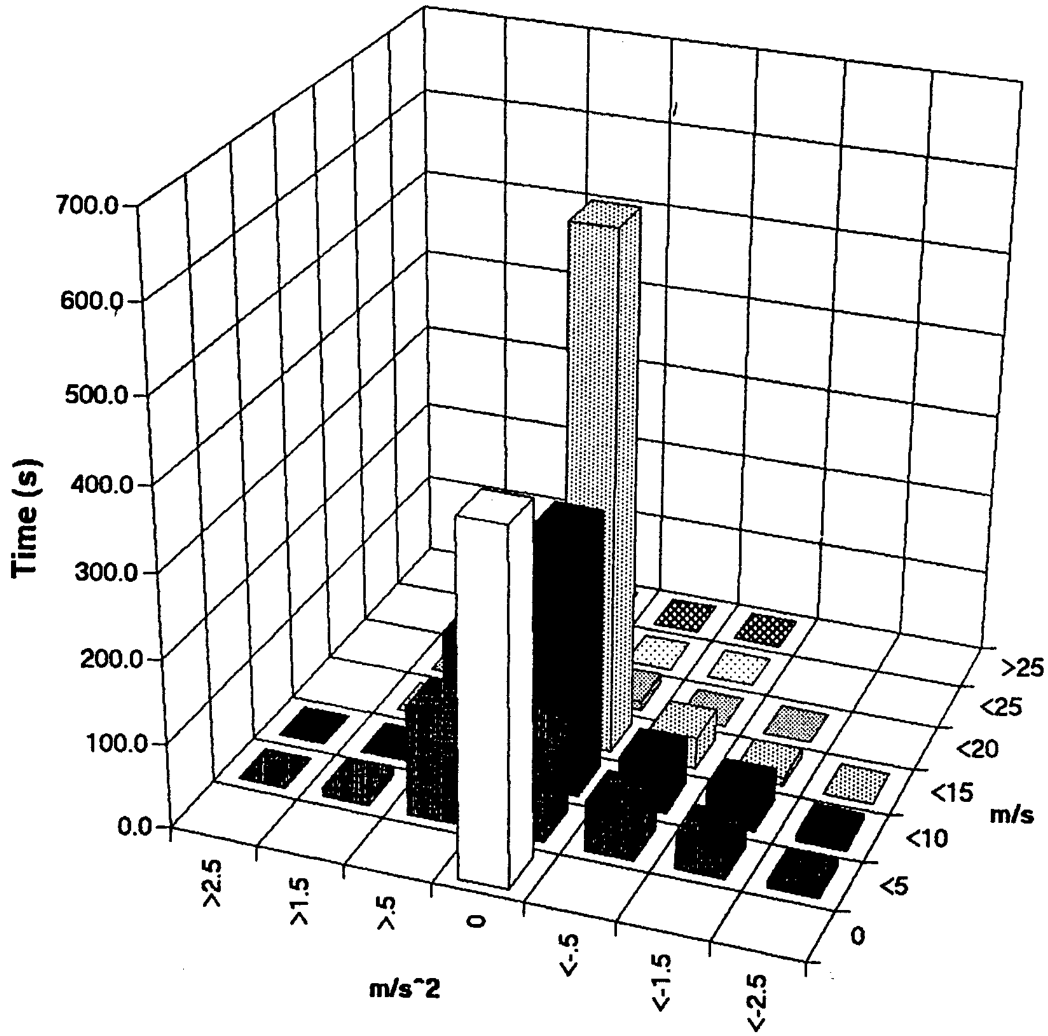
City-el Trip Times

Date: 9-11-94 10:26 AM

VIN: 4135

Trip Data:

22.7	Deg. C
13797	Meters
740	Watt-hours
86	Wh/mile
31%	Efficiency



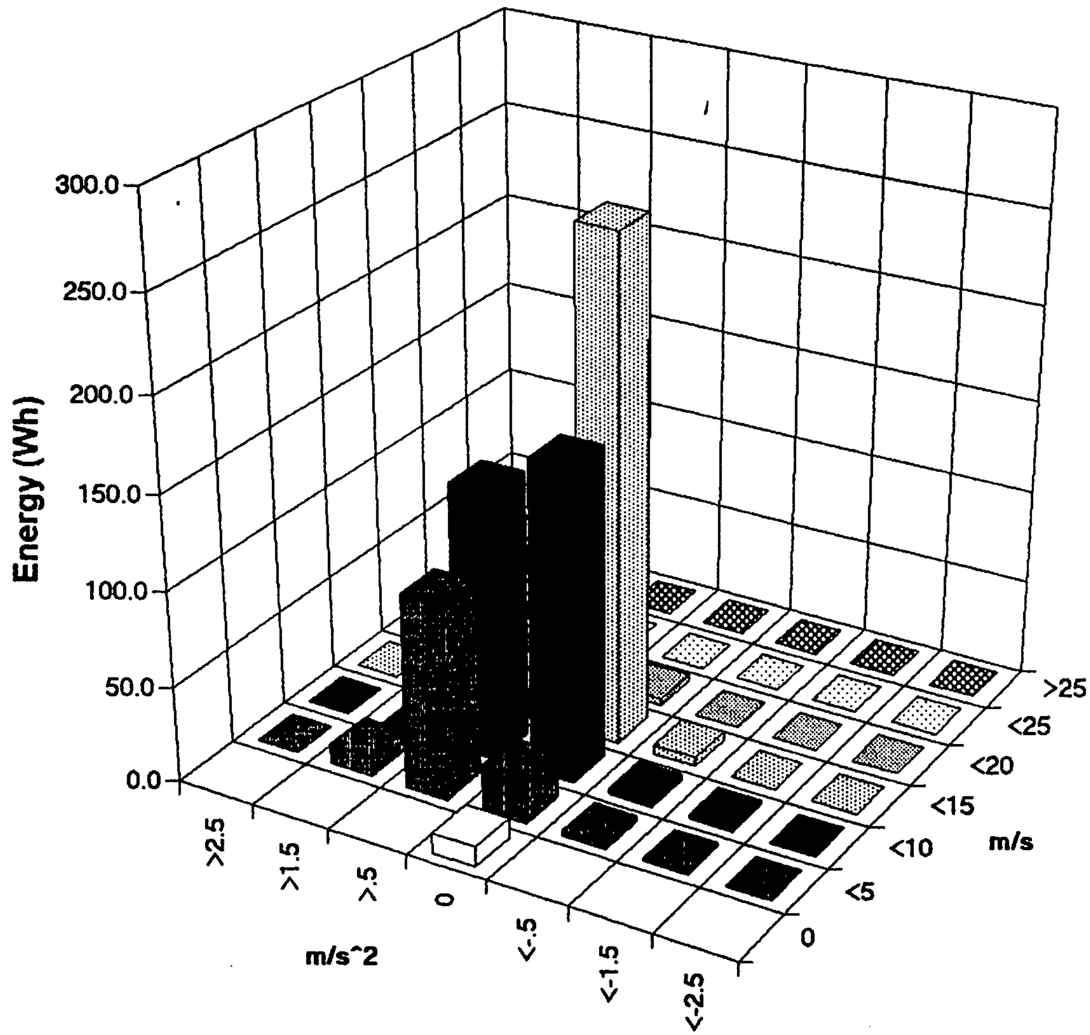
City-el Trip Performance

Date: 9-11-94 10:26 AM

VIN: 4135

Trip Data:

22.7	Deg. C
13797	Meters
740	Watt-hours
86	Wh/mile
31%	Efficiency



Efficiency = (theoretical power)/(measured power) for bins with valid data

%	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5		49%						
>.5		40%	81%					
0		15%	39%	73%				
<-.5								
<-1.5								
<-2.5								

meters/sec^2

Power loss = measured power - theoretical power

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5		1768						
>.5		1710	656	-1545				
0	95	639	1195	493	-219			
<-.5		656	2333	3591				
<-1.5		2099	5662	6731				
<-2.5		3850	6802					

meters/sec^2

Energy = power * time for bins with more than 3 seconds

Watt-hour	0	<5	<10	<15	<20	<25	>25	m/s	
>2.5									
>1.5		10.3							
>.5		102.2	141.3	10.0					
0	11.0	24.6	164.7	266.1	3.5				738
<-.5		2.6	3.2	4.8					
<-1.5		1.6	1.6	0.4					
<-2.5		0.4	0.3						

meters/sec^2

Waste Energy = power loss * time for bins with more than 3 seconds

Watt-hour	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5		5.4						
>.5		62.2	30.1	-8.2				
0	11.0	21.3	103.5	84.8	-0.7			
<-.5		10.7	36.9	37.9				
<-1.5		22.7	62.9	18.7				
<-2.5		9.6	13.2					

meters/sec^2

Theoretical energy = theoretical power * time for bins with more than 3 seconds

Theoretic	0	<5	<10	<15	<20	<25	>25	
>2.5								
>1.5		4.9						
>.5		39.9	111.2	18.1				
0	0.0	3.3	61.1	181.3	4.1			226
<-.5		-8.1	-33.8	-33.1				
<-1.5		-21.1	-61.3	-18.3				
<-2.5		-9.3	-12.9					

meters/sec^2

Tractive Power = (measured power for bins with more than 3 seconds)-idle power

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5		3277						
>.5		2713	2989	1796				
0	0	644	1806	1451	1040			
<-.5		66	105	361				
<-1.5		55	51	49				
<-2.5		52	50					

meters/sec^2

Power = (measured power for bins with more than 3 seconds)

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5		3372						
>.5		2808	3083	1890				
0	95	739	1900	1545	1135			
<-.5		160	200	456				
<-1.5		149	146	143				
<-2.5		147	145					

meters/sec^2

% of time = (time spent in bins with more than 3 seconds)/(total time for trip)

% Time	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		0%	0%					
>1.5		1%	0%	0%	0%			
>.5		6%	8%	1%	0%	0%	0%	
0	20%	6%	15%	30%	1%	0%	0%	100%
<-.5		3%	3%	2%	0%	0%	0%	
<-1.5		2%	2%	0%	0%			
<-2.5		0%	0%	0%				

meters/sec^2

% of energy = (energy used in bins with more than 3 seconds)/(total energy for trip)

% energy	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5		1%						
>.5		14%	19%	1%				
0	1%	3%	22%	36%	0%			101%
<-.5		0%	0%	1%				
<-1.5		0%	0%	0%				
<-2.5		0%	0%					

meters/sec^2

m= 377 kg
Cd= 0.4
Croll= 0.01
A= 0.99 m^2

Theoretical power = ((Cd*A*vel^2)+(m*g*Croll)+(m*acc))*vel

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5		1604						
>.5		1097	2427	3435				
0	0	99	706	1053	1353			
<-.5		-495	-2133	-3135				
<-1.5		-1949	-5516	-6588				
<-2.5		-3703	-6658					

meters/sec^2

City-el DAS Trip Analysis

Trip Data:

9-11-94 Date	13797 meters	vin # 4135
10:26 AM Time	740 Watthours	
22.7 deg C	86 Wh/mile	% Eff. 31%

Data Acquisition System Bin Numbers

BINS	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		1	8					
>1.5		2	9	15	21			
>.5		3	10	16	22	26	29	
0	32	4	11	17	23	27	30	
<-.5		5	12	18	24	28	31	
<-1.5		6	13	19	25			
<-2.5		7	14	20				

meters/sec^2

Time = number of seconds spent in each bin

seconds	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		0.0	0.0					
>1.5		11.0	0.0	0.0	0.0			
>.5		131.0	165.0	19.0	0.0	0.0	0.0	
0	417.0	120.0	312.0	620.0	11.0	0.0	0.0	2065
<-.5		59.0	57.0	38.0	0.0	0.0	0.0	
<-1.5		39.0	40.0	10.0	0.0			
<-2.5		9.0	7.0	0.0				

meters/sec^2

Velocity = average velocity over time spent in each bin

m/s	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		0.00	0.00					
>1.5		2.40	0.00	0.00	0.00			
>.5		2.57	7.33	11.15	0.00	0.00	0.00	
0	0.00	2.02	8.56	11.85	15.53	0.00	0.00	
<-.5		1.62	7.53	11.78	0.00	0.00	0.00	
<-1.5		2.68	7.87	11.25	0.00			
<-2.5		3.67	6.77	0.00				

meters/sec^2

Acceleration = average acceleration over time spent in each bin

m/s^2	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		0.00	0.00					
>1.5		1.67	0.00	0.00	0.00			
>.5		1.03	0.75	0.65	0.00	0.00	0.00	
0	0.00	0.03	0.08	0.06	0.00	0.00	0.00	
<-.5		-0.91	-0.88	-0.88	0.00	0.00	0.00	
<-1.5		-2.03	-1.99	-1.72	0.00			
<-2.5		-2.78	-2.73	0.00				

meters/sec^2

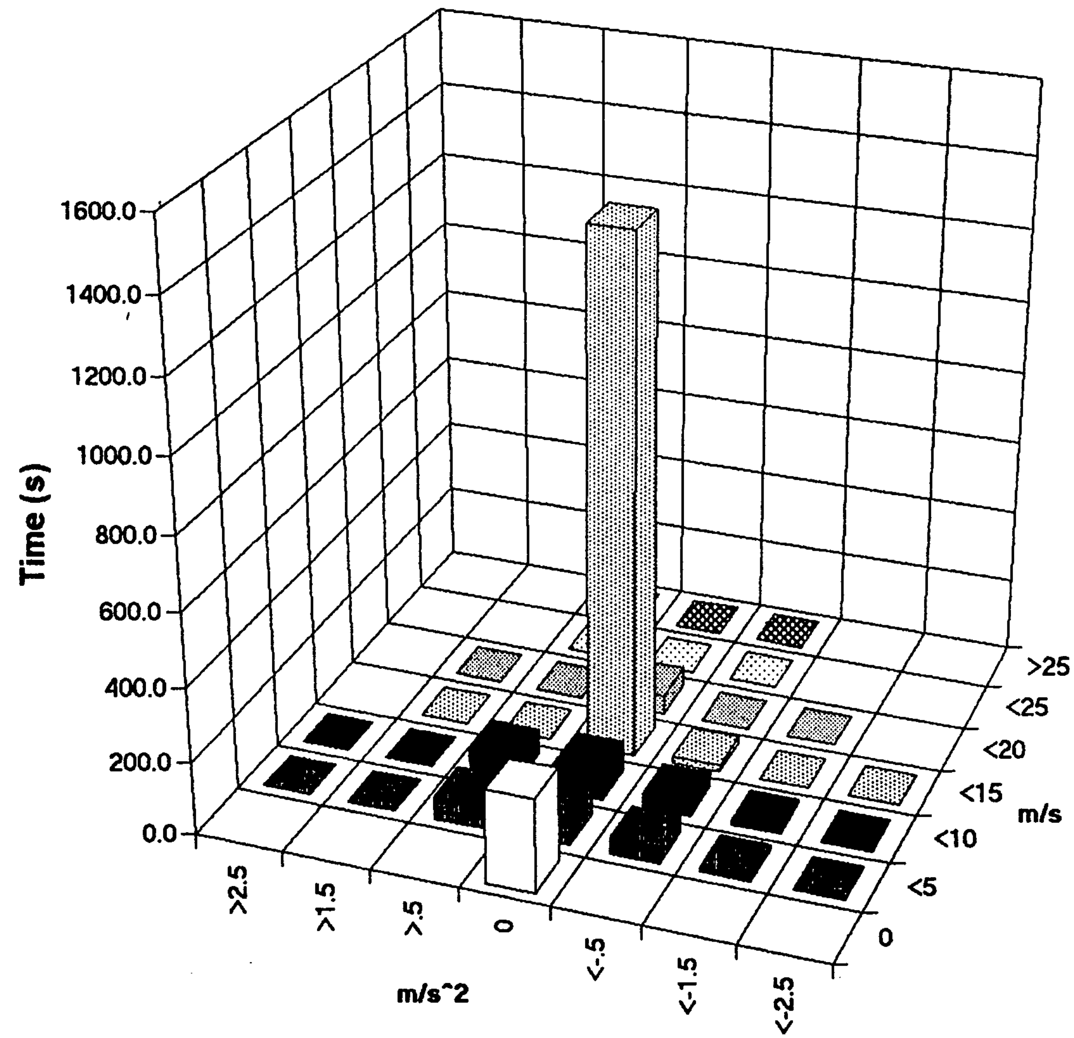
City-el Trip Times

Date: 9-9-94 3:20 PM

VIN: 4135

Trip Data:

30.6	Deg. C
21276	Meters
725	Watt-hours
55	Wh/mile
58%	Efficiency



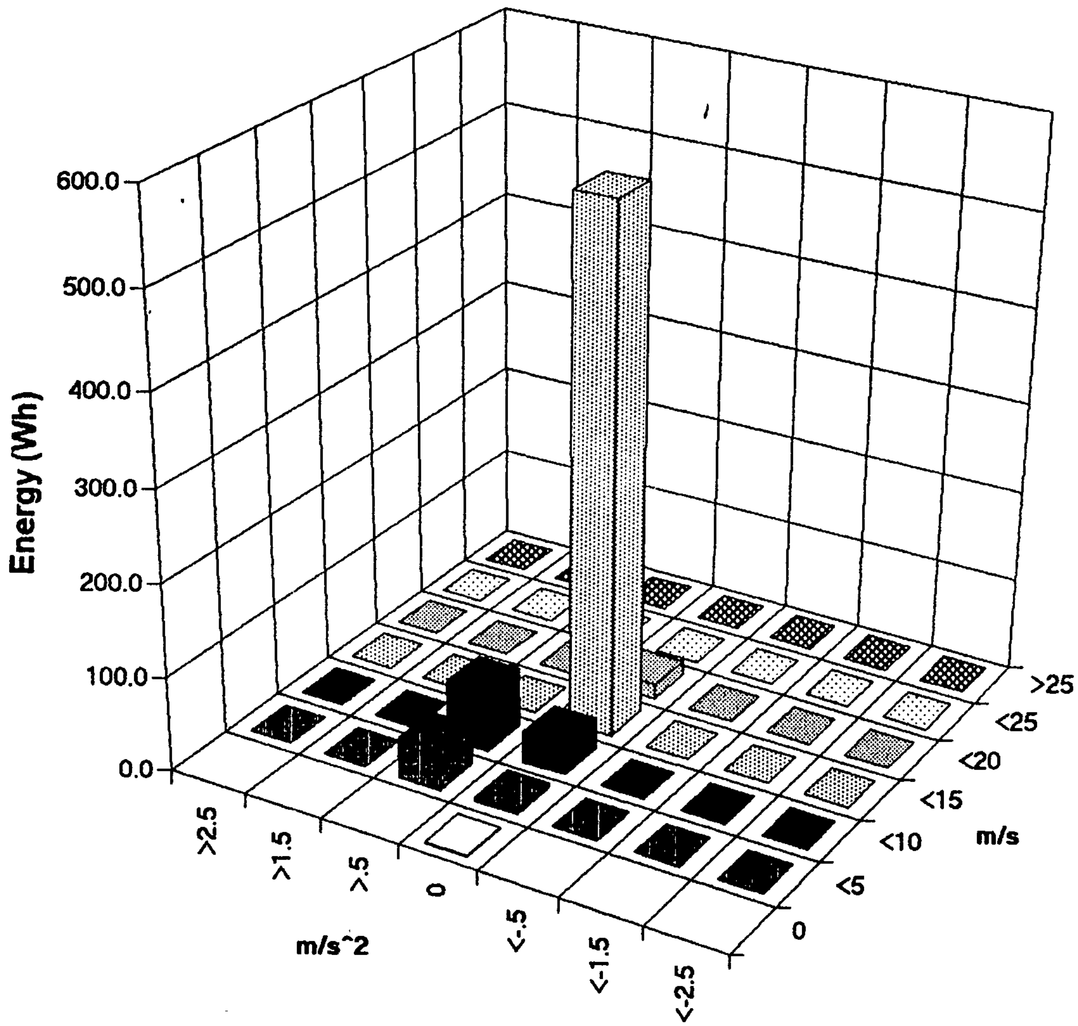
City-el Trip Performance

Date: 9-9-94 3:20 PM

VIN: 4135

Trip Data:

30.6	Deg. C
21276	Meters
725	Watt-hours
55	Wh/mile
58%	Efficiency



Efficiency = (theoretical power)/(measured power) for bins with valid data

%	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5								
>.5		39%	75%					
0		26%	58%	69%				
<-.5								
<-1.5								
<-2.5								

meters/sec^2

Power loss = measured power - theoretical power

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5								
>.5		1571	782					
0	18	199	635	458	-304			
<-.5		700	2482	3287				
<-1.5		1962	4491					
<-2.5								

meters/sec^2

Energy = power * time for bins with more than 3 seconds

Watt-hour	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5								
>.5		43.4	62.5					
0	1.3	4.8	33.7	562.6	15.0			724
<-.5		0.7	0.6	0.3				
<-1.5		0.2	0.2					
<-2.5								

meters/sec^2

Waste Energy = power loss * time for bins with more than 3 seconds

Watt-hour	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5								
>.5		26.6	15.6					
0	1.3	3.7	14.3	180.1	-4.2			
<-.5		8.9	26.9	16.4				
<-1.5		6.5	12.5					
<-2.5								

meters/sec^2

Theoretical energy = theoretical power * time for bins with more than 3 seconds

Theoretic	0	<5	<10	<15	<20	<25	>25	
>2.5								
>1.5								
>.5		16.8	46.8					
0	0.0	1.2	19.4	382.5	19.2			417
<-.5		-8.2	-26.3	-16.2				
<-1.5		-6.3	-12.3					
<-2.5								

meters/sec^2

Tractive Power = (measured power for bins with more than 3 seconds)-idle power

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5								
>.5		2543	3105					
0	0	244	1479	1415	1060			
<-.5		39	40	39				
<-1.5		41	45					
<-2.5								

meters/sec^2

Power = (measured power for bins with more than 3 seconds)

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5								
>.5		2561	3123					
0	18	262	1496	1432	1078			
<-.5		57	57	57				
<-1.5		59	63					
<-2.5								

meters/sec^2

% of time = (time spent in bins with more than 3 seconds)/(total time for trip)

% Time	0	<5	<10	<15	<20	<25	>25	m/s	
>2.5		0%	0%						
>1.5		0%	0%	0%	0%				
>.5		3%	3%	0%	0%	0%	0%		
0	12%	3%	4%	66%	2%	0%	0%		100%
<-.5		2%	2%	1%	0%	0%	0%		
<-1.5		1%	0%	0%	0%				
<-2.5		0%	0%	0%					

meters/sec^2

% of energy = (energy used in bins with more than 3 seconds)/(total energy for trip)

% energy	0	<5	<10	<15	<20	<25	>25	m/s	
>2.5									
>1.5									
>.5		6%	9%						
0	0%	1%	5%	78%	2%				100%
<-.5		0%	0%	0%					
<-1.5		0%	0%						
<-2.5									

meters/sec^2

m= 377 kg
Cd= 0.4
Croll= 0.01
A= 0.99 m^2

Theoretical power = ((Cd*A*vel^2)+(m*g*Croll)+(m*acc))*vel

Watts	0	<5	<10	<15	<20	<25	>25	m/s
>2.5								
>1.5								
>.5		990	2340					
0	0	63	862	974	1382			
<-.5		-643	-2425	-3230				
<-1.5		-1903	-4428					
<-2.5								

meters/sec^2

City-el DAS Trip Analysis

Trip Data:

9-9-94 Date	21276 meters	vin # 4135
3:20 PM Time	725 Watthours	
30.6 deg C	55 Wh/mile	% Eff. 58%

Data Acquisition System Bin Numbers

BINS	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		1	8					
>1.5		2	9	15	21			
>.5		3	10	16	22	26	29	
0	32	4	11	17	23	27	30	
<-.5		5	12	18	24	28	31	
<-1.5		6	13	19	25			
<-2.5		7	14	20				

meters/sec^2

Time = number of seconds spent in each bin

seconds	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		0.0	0.0					
>1.5		2.0	0.0	0.0	0.0			
>.5		61.0	72.0	3.0	0.0	0.0	0.0	
0	259.0	66.0	81.0	1414.0	50.0	0.0	0.0	2135
<-.5		46.0	39.0	18.0	0.0	0.0	0.0	
<-1.5		12.0	10.0	0.0	0.0			
<-2.5		1.0	1.0	0.0				

meters/sec^2

Velocity = average velocity over time spent in each bin

m/s	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		0.00	0.00					
>1.5		3.31	0.00	0.00	0.00			
>.5		2.30	7.16	10.36	0.00	0.00	0.00	
0	0.00	2.35	8.52	12.91	15.68	0.00	0.00	
<-.5		2.03	7.37	11.23	0.00	0.00	0.00	
<-1.5		3.12	6.88	0.00	0.00			
<-2.5		4.61	8.05	0.00				

meters/sec^2

Acceleration = average acceleration over time spent in each bin

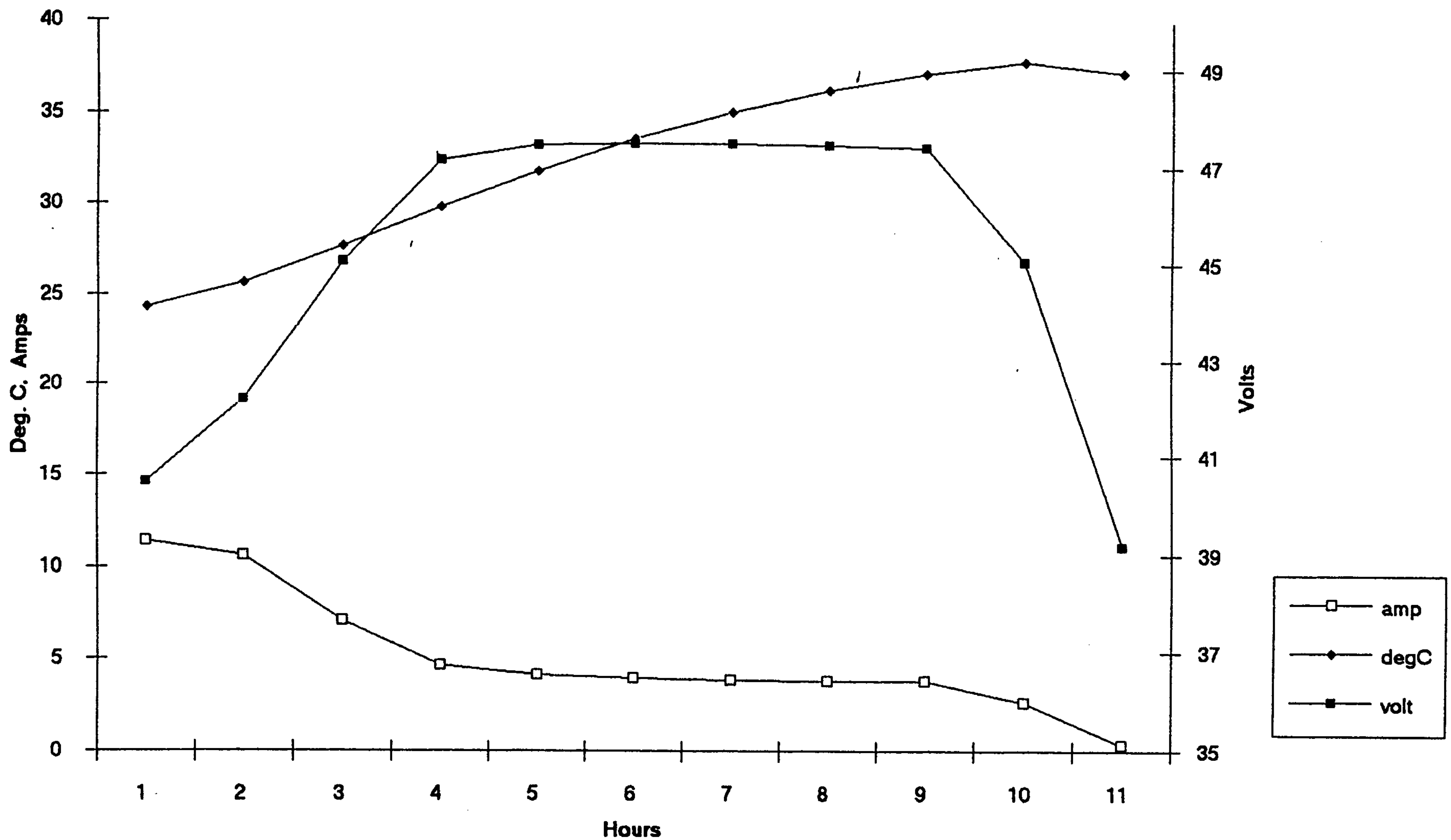
m/s^2	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		0.00	0.00					
>1.5		1.79	0.00	0.00	0.00			
>.5		1.04	0.74	0.56	0.00	0.00	0.00	
0	0.00	-0.03	0.13	0.01	0.00	0.00	0.00	
<-.5		-0.94	-1.00	-0.93	0.00	0.00	0.00	
<-1.5		-1.72	-1.83	0.00	0.00			
<-2.5		-2.97	-2.73	0.00				

meters/sec^2

Date: 9-8-94 12:34 PM

VIN: 4135

City-el Charge Profile



City-el DAS Charge Data

VIN#: 4135
Date: 9-8-94
Time: 12:34 PM

hour	AC W	volt	amp	degC	DC kWh
1	735	40.47	11.39	24.31	0.46
2	699	42.19	10.6	25.65	0.91
3	504	45.05	7.1	27.68	1.23
4	371	47.15	4.64	29.81	1.45
5	342	47.47	4.14	31.81	1.64
6	333	47.51	3.94	33.62	1.83
7	328	47.5	3.85	35.11	2.01
8	319	47.47	3.81	36.27	2.19
9	304	47.41	3.79	37.14	2.37
10	217	45.06	2.62	37.8	2.49
11	54	39.18	0.32	37.2	2.50
12	44	39.44	0.26	29.8	2.51

Test Report, City-el Constant Power Drains.

29 September, 1994

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

TEST REPORT: City-el Constant Power Drains.

Prepared by: Lance Atkins, Pacific Electric Vehicles, 9-29-94

Purpose: This report documents which components contribute to the constant power drain in the City-el. It further quantifies the magnitude of the total power drain and determines the power drain for each individual component.

Scope: The test methodology and results are described below. Descriptions of the attached spreadsheet and chart are also provided below. Refer to the appendix for the spreadsheet and the chart.

Results: Power drain in the City-el can be attributed to three components. The capacity gage, charger, and DC to DC converter all use a constant amount of power in the City-el even when the City-el is turned off and unplugged. Total power drain is about 2.94 Watts. The capacity gage uses 1.51 Watts while the charger uses 0.38 Watts and the DC to DC converter uses 1.05 Watts. Variations from City-el to City-el have not been explored. Furthermore, possible variations due to differences in battery voltage and ambient temperature have also not been explored.

Test Initial Conditions.

This test was performed twice because the first test could not be completed with the same instruments due to instrument problems. It also provides two sets of data to be averaged. The first test was performed at Pacific EV on 8-13-94. The second test was performed in Carmichael on 9-14-94. Both tests were performed by Arthur Cartwright and Lance Atkins using City-el 4135 which by 9-14-94 had covered 529.7 miles.

Test Setup and Procedure

Before beginning the test, the Pacific EV prototype DAS was disconnected from the vehicle. The Cruising Equipment meter installed in 4135 was also disconnected. This was done to avoid the power drains associated with these components. To determine which components might have a constant power drain the City-el schematics were studied. It was found that the capacity gage, charger, and DC to DC converter were all hooked directly to the battery and might, therefore, have a constant power drain. Each component power drain was then measured by measuring the current to and voltage around the component. Refer to the City-el schematic in the appendix for the locations of the measurements described in the following paragraphs.

Total current out of the battery pack was measured at the positive terminal of the battery pack. The meter used for this was left in the line for the duration of the test. The attached spreadsheet indicates which meters were used for what measurements. After each component measurement was done, the total current was then checked followed by the battery pack voltage.

The DC to DC converter current measurement was done at the 36V input to the board. Voltage was measured between the 36V input and the ground wire that leaves the board. The current measurement was done first followed by the voltage measurement.

Current used by the charger was measured at J39 which is the output ground wire. Voltage was measured between J38 which is the 36V input and the ground J39.

For the capacity gage current, fuse F3 was removed and the meter installed in the line. Informal tests showed that the capacity gage used the same amount of current before and after resetting the gage by removing fuse F3. Voltage was measured between J1 pin1 and J1 pin2. These are the 36V input and ground wires.

Test Equipment.

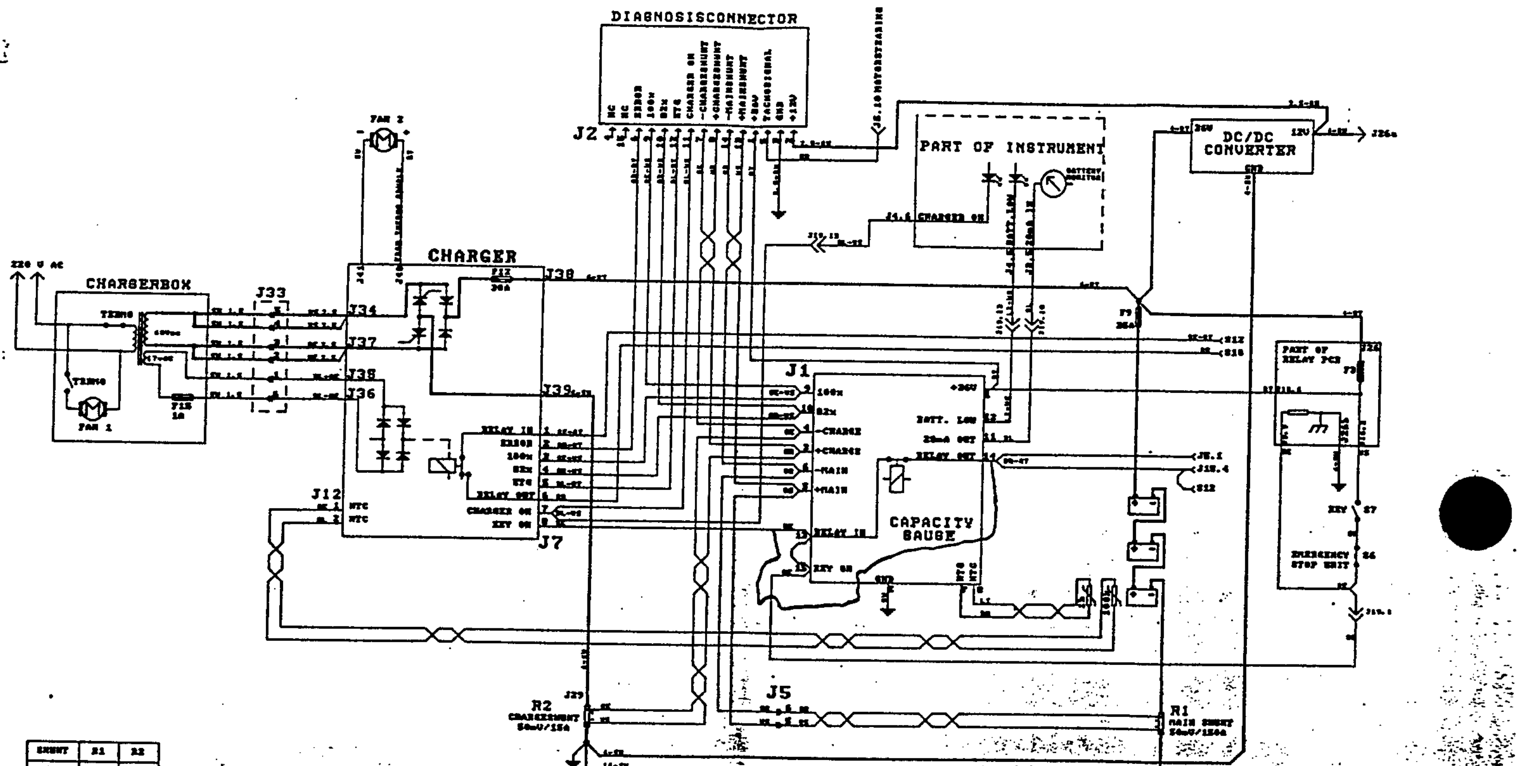
Equipment	Model	S/N
Vehicle	City-el	4135
Multimeter	Fluke 21 Series II Multimeter	58570412
Multimeter	Kelvin 400 LE	24001215
Multimeter	Micronta No 22-182	CJ062859

Data Descriptions

Raw data for the test was entered in the spreadsheet titled City-el Constant Power Drain. This is Pacific EV file PHANTOM.XLS. See the appendix for a copy of this spreadsheet. For each test, the voltage and miliamp readings were recorded for the component and for the total battery pack output. The Watts column computes the power use for the component using the formula: (V*mA)/1000. The Tot. Watts column computes the total power drain using the same formula on the total values. The Average section computes the average voltage and miliamp values from the two tests. The instrument used for each measurement is noted.

From the data described above, The chart City-el Constant Power Drains was generated. Refer to the appendix for this chart. The data for this chart is taken from the average Watts column. Capacity gage drain is shown to be 1.51 Watts. Power drain from the charger is 0.38 Watts, and the DC to DC converter uses 1.05 Watts. Total Power used is 2.94 Watts.

APPENDIX



SHUNT	R1	R2
10mV	30A	3A
20mV	60A	6A
30mV	90A	9A
40mV	120A	12A
50mV	150A	15A

	ON	OFF
FAN 1	60 degC	55 degC
FAN 2	50 degC	45 degC

NTC THERMOCOUPLE		
TEMP.	CHARGER	CAPACITY
25 degC	100k ohm	1.00k ohm
15 degC	150k ohm	1.48k ohm
0 degC	340k ohm	2.40k ohm
-10 degC	500k ohm	5.00k ohm

CityCom	Workshop Manual	Section/Group: 7/2	No.: 3.1-0
			Page 1 of 1
Date: 920907	Model:		Replaces:
Prepared by: KJ	Subject: Charger and Capacity Gauge		From VIN no.: 3006
			To VIN no.:

City-el Constant Power Drain

Dates: 8-13-94
9-14-94

8-13-94 Test

	Component		Total			Analysis	
Component	V	mA	V	mA	Meter:	Watts	Tot. Watts
DC to DC converter	36.6	28.1	37.1	84.2	<--Fluke	1.03	3.12
Charger	36.5	8.6	37.1	84.2	<--Fluke	0.31	3.12
Capacity Gage	36.9	45.3	37	100.2	<--Micronta	1.67	3.71
Meter:	Kelvin--^	Kelvin--^	Kelvin--^				
Totals:		82				3.01	

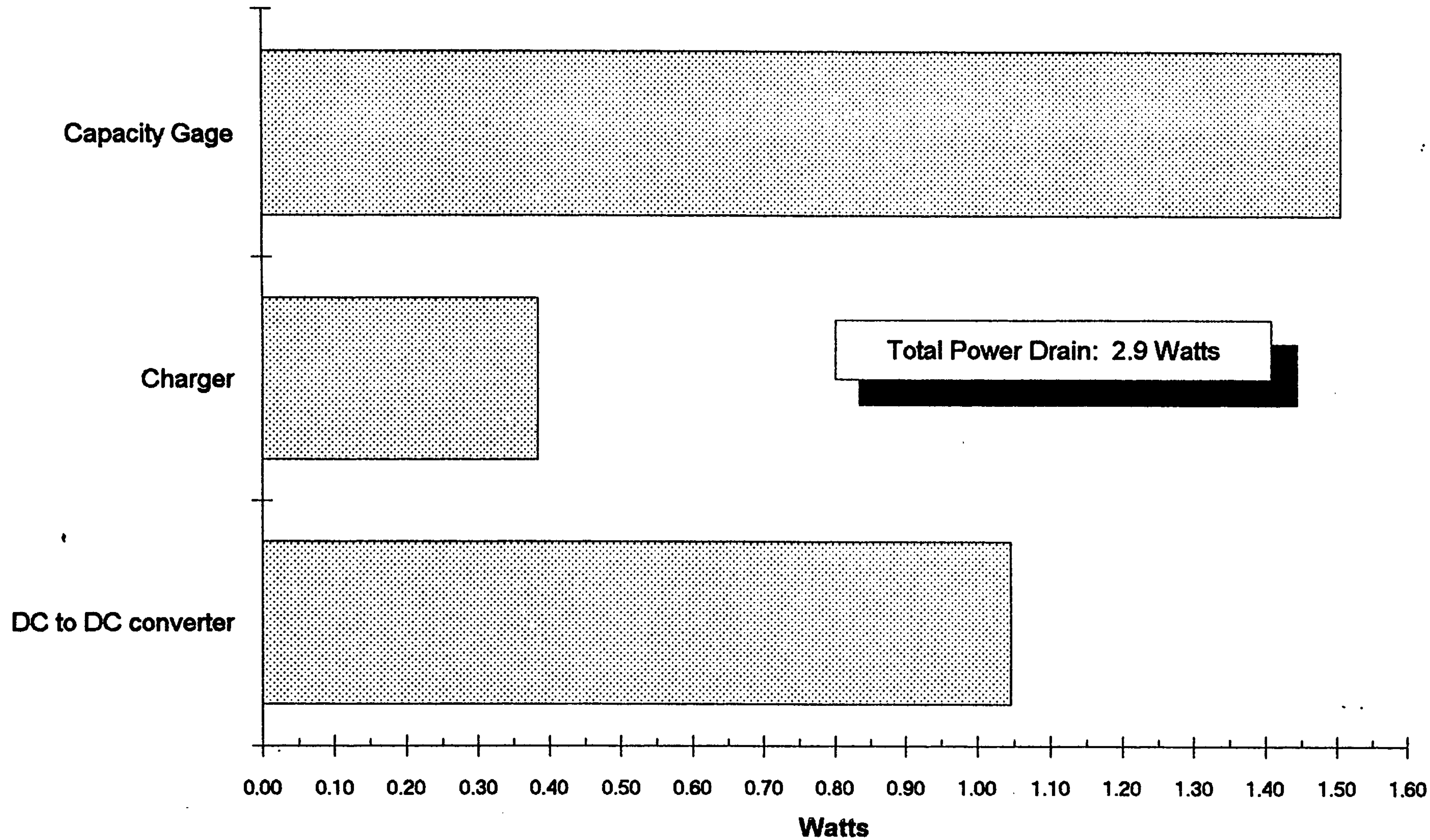
9-14-94 Test

	Component		Total			Analysis	
Component	V	mA	V	mA	Meter:	Watts	Tot. Watts
DC to DC converter	37.5	28.4	37.5	87.9	<--Kelvin	1.07	3.30
Charger	37.4	12.2	37.5	87.9	<--Kelvin	0.46	3.30
Capacity Gage	37.4	35.8	37.5	87.8	<--Kelvin	1.34	3.29
Meter:	Fluke--^	Fluke--^	Fluke--^				
Totals:		76.4				2.86	

Average

	Component		Total		Analysis	
Component	V	mA	V	mA	Watts	Tot. Watts
DC to DC converter	37.05	28.25	37.3	86.05	1.05	3.21
Charger	36.95	10.4	37.3	86.05	0.38	3.21
Capacity Gage	37.15	40.55	37.25	94	1.51	3.50
Totals:		79.2			2.94	

City-el Constant Power Drains



Test Report:

PEPCO TURBO-Z CHARGER USE ON A City-el
Neighborhood Electric Vehicle Product Test and Development Project

Prepared By:
William R. Warf
Lance L. Atkins
Pacific Electric Vehicles
December 31, 1994

This Project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

Summary:
A TURBO-Z 36 volt battery charger provided by PEPCO was tested on a City-el electric vehicle on 15 December, 1994, at McClellan Air Force Base. The PEPCO charger reduced the time needed to charge the City-el pack by a factor greater than two. The PEPCO charger delivers energy to the batteries with an efficiency of 75%, compared to the City-el chargers 61% or less efficiency.

While the City-el charger is programmed to overcharge the batteries by a factor of 2 or more, the PEPCO charger provides less than the 2 hour Trojan specification for equalizing time. This results in a best energy use measurement of 117 AC W-h/mile using the PEPCO TURBO-Z, compared to a best 241 AC W-h/mile using the City-el charger.

Although inefficient, the City-el charger consistently charges the batteries to a 1.28 specific gravity, which is within the Trojan Engineering specification tolerance for 30XH batteries (1.277 +/- .008). The PEPCO TURBO-Z in it's initial test configuration provided an end specific gravity of 1.240-1.250. The length of the finish charge provided by the TURBO-Z can be increased, which will increase the finished specific gravity.

There were no problems encountered in charging the 30XH batteries at a 20 Amp rate. This rate is in fact very close to Trojan's recommended C/5 rate for these batteries. The TURBO-Z heated the batteries only 2 to 3 degrees C, compared to the City-el charger's heating them 9 to 13 degrees C.

Recommendation: The TURBO-Z should be put in regular use. There is no doubt that overall reduction in energy use of the City-el's will be achieved. If the TURBO-Z was used for opportunity charging, and the City-el charger used on every other charge, energy use on the order of 230 AC W-h/mile could be realized. If the TURBO-Z was re configured to match the Trojan specification provided in Appendix 1, energy use on the order of 150 AC W-h/mile is expected.

Introduction:
This Test Report provides an initial evaluation of the PEPCO TURBO-Z battery charger for use in charging City-el batteries in the vehicle fleet at McClellan Air Force Base. The TURBO-Z was furnished by PEPCO, and as furnished was configured to provide a charge rate of 20 Amps, as opposed to it's normal 40 Amp configuration used to charge golf cart 6 V batteries. A 20 Amp rate was chosen as a starting point for the City-el pack consisting of three 30XH Trojan 12 V batteries. The City-el charger normally charges at a 10 Amp initial rate.

The test was performed between December 14 and December 16, by charging batteries with the City-el charger and the PEPCO charger after discharging the batteries in a normal driving cycle. The condition of the of the batteries was recorded after each charge and discharge cycle, and data about each cycle was recorded.

The main purpose of the test was to determine how the City-el battery pack responded to a faster charge, and to determine if the overall energy use of the City-el might be reduced through the application of this charger over a longer time period.

Test Description:
City-el 4135 was used for the test. This vehicle was driven through several discharge cycles before the test to characterize the batteries, and calibrate the data acquisition system. Batteries were Trojan 30XH, installed in the vehicle in late November, 1993. Vehicle mileage at the time of testing was 627 miles.

The City-el charger on this vehicle was consistently bringing the batteries to a finished specific gravity of 1.28, and an open circuit pack voltage of 39-40 volts. The energy consumption of this vehicle for the month of December was 557 W-h/ mile.

City-el 4135 was fitted with a 25 Amp shunt (50 mV / 25 Amps), to allow the DAS to record the test charges. The normal City-el shunt is rated at 50 mV / 15 Amps.

The vehicle was driven to and around McClellan Air Force Base on December 14. The trip length was 24.72 miles, and the total DC discharge as measured on the Cruising equipment meter was 1800 W-h DC. The City-el was plugged in overnight. It is worth noting the energy consumption recorded by the data acquisition system (DAS) was 2159 W-h DC for this discharge. The 20% difference is attributed to inconstancies in equipment calibration. We do not know which is more accurate, and therefore have consistently used DC energy measurements from the Cruising Equipment Meter W-h meter throughout this report. DAS data is provided in the appendix to this report, for reference. The Cruising Equipment energy data for charging is compared with manual data later in this report as a check.

The City-el was charged for 12 hours using the City-el Charger. Total recharge energy was 3650 W-h DC and 5958 W-h AC. The AC energy use for the 24.72 mile trip on the previous day was 241 W-h/mile. The charger was unplugged at 5:18 AM on 12/15/94. After waiting one hour the average specific gravity for all cells was measured as 1.280, and the open circuit voltage was 39 V. Examination of DAS data for this charge shows a total temperature rise of the batteries of 8.8 degrees C to an end temperature of 21.3 C.

A 10.89 mile trip with the heater, fan, and lights on was completed at 7:20 AM with 5 dots remaining on the capacity gage. DC energy for the trip was 900 W-h, or 82.61 DC W-h/ mile as measured on the Cruising Equipment W-h meter. End specific gravity and pack open circuit voltage were measured at 9:22 AM as about 1.230 average and 38.0 Volts respectively.

Testing accomplished on 12/15/94 was performed by Bill Warf and Lance Atkins of Pacific Electric Vehicles and Jeff Rose of PEPCO.

The PEPCO Charger was connected to the City-el, by connecting the negative lead to the charge shunt, and the positive lead to the positive battery post using the installation kit provided by PEPCO. Wires from the City-el charger to the system were disconnected at the Charger printed circuit board. Charging commenced with the PEPCO TURBO-Z at 10:10 AM at a rate of 19.45 Amps, (38.9mV measured with a Fluke meter across the charging shunt).

We immediately noticed that the Data Acquisition system was unable to record the charge voltage or current. Measurements across the system voltage leads suggested a pulse frequency of 400 cycles per second. The sampling frequency of the DAS is 200 cycles per second, and recording the charge profile of the PEPCO charger with the DAS was not possible. Charge data was therefore recorded manually using a fluke meter to measure system voltage and current at regular 10 minute intervals.

Charging continued at a rate of 19.4 amps for about 45 minutes. At this time the pack voltage reached 44.1 Volts (2.45 Volts per cell), and the charger began stepping down the current in approximately 0.9 Amp increments each time the voltage reached 2.45 vpc. The current reached the 15 th and final step between 11:20 and 11:30 AM, at which time the current was 6.15 Amps as measured at the charge shunt. After reaching this final charge rate, the PEPCO charger releases the voltage, and charges for a fixed period of time at the final rate. In this test the charge was terminated at 11:40 AM when the pack voltage reached 48.5 volts. Jeff Rose of PEPCO stated the charger must have reached it's high voltage limit and terminated charging.

Total charge energy was 1469 AC W-hours as measured on the 240 V AC Watt hour meter furnished by PEPCO, and 1100 DC W-h measured on the Cruising Equipment meter. Total energy use for the previous 10.89 mile trip was 135 AC W-h/mile. Battery temperature rise recorded by the DAS during the charge was 2.03 degrees C to an end temperature of 13.89 C.

Specific Gravity of the batteries averaged 1.250 at 12:42 PM. Open circuit pack voltage was 40.0 V.

A 27.2 mile trip around McClellan was started at 1:06 PM, and completed at 2:20 PM. Total discharge was 1800 DC W-h, or 66 DC W-h/ mile. At 2:45 the specific gravity averaged 1.160, and the open circuit voltage was 36.5 volts. This discharge level, about 50 A-h, matches a full discharge of the City-el as indicated by the capacity gage.

For the second TURBO-Z charge, Jeff Rose adjusted a potentiometer on the charger control board to provide a lower initial rate, which would also provide a lower finish rate after the 15 current steps. Charging commenced at 3:05 PM at a rate of 17.55 Amps measured at the charging shunt.

Charging continued at this rate until 5:40 PM (2hours, 35 minutes), when the pack voltage reached 44 V and the current was 14.91 A.

At this point we decided to record data at the time the charger stepped the current down. We managed to record 11 of the 15 steps. At the beginning of the step down phase the charger switches quickly as the voltage limit is quickly reached at higher rates. The current measured at 5:45 was 12.3 Amps, at 5:47 it was 11.40 A, at 5:50 it was 10.52 A, and at 5:53 it was 9.6 Amps. At 6:21 PM we reached a 4.35 Amp final rate, which was continued until 7:35 PM. Peak pack voltage recorded was 47.7 V at 7:21 PM. Energy use for the charge was 2360 DC W-h and 3194 AC W-h. Energy use for the previous 27.2 mile trip was 117.39 AC W-h/ mile. Battery temperature rise during the charge was 3.14 degrees C to 19.9 C. It is noted that vigorous gassing of the batteries wasn't observed visually until the pack reached 47 V and 4 Amps at 7 PM.

At this point we called it a day, and loaded the equipment to go home. The following morning at 8:58 AM the specific gravity of the pack averaged 1.240, and the open circuit voltage was 40.5 Volts.

On 12/16/94 the City-el was driven 12.6 miles from McClellan to PEV and recharged with the City-el Charger. The batteries were left on the charger until 12/19 at 9:10, or for 67 hours. Approximately 44 hours of this time was holding charge at 2.25 Volts per cell, and about 0.4 Amps. Because of the extended holding charge, the AC energy was 7126 AC W-h and the DC energy was 2710 DC W-h. Efficiency of the City-el charger was a low 38% overall, and the energy use for the 12.6 mile trip was 565.4 W-h/mile. During the charge the battery temperature rose 13.25 degrees C to 27.23 C. It is noted the vehicle was charged indoors, where ambient was at least 15 C, compared to 8 - 10 C outside ambient during the PEPCO tests.

At 10:10 the battery specific gravity averaged 1.280, and the open circuit pack voltage was 39 Volts.

Notes about DC Energy Use:
Throughout this report DC energy values taken from the Cruising Equipment Watt-Hour meter have been used. Since this meter is not calibrated, a check of the charging energy recorded was performed by multiplying the current times the voltage times the time interval recorded in

the second TURBO-Z charge, to estimate the DC energy. Current and Voltage values used were recorded with a Fluke 79 Series II multimeter. The result of this calculation gave a value of 2276 DC W-h accumulated for the second charge at 19:21 (7:30 PM), 1.5 % lower than the Cruising Equipment meters value of 2310 at the same time. It appears the energy recorded during this charge is in reasonable agreement.

As previously noted discharge energy recorded by the Cruising Equipment meter does not agree with DC energy use recorded by the vehicles DAS. Comparisons or calibrations should be done at a later date to establish the accuracy of the instruments used to record driving energy.

Notes about the Batteries:
The Trojan 30XH deep cycle batteries used in the City-el we tested are rated at 105 Amp-hours at the 20 hour rate. The Trojan Engineering specification for specific gravity is 1.277 +/- .008. According to Trojan, these batteries should be good for about 350 cycles in electric vehicle use. The batteries used in the test are thought to have approximately 150 cycles on them.

The Trojan charging specification states they should be charged at a constant current of C/5=105/5=21 Amps to a voltage limit of about 2.37 Volts per Cell. After reaching 2.37 VPC the current should be tapered to C/20=5.25 Amps at a constant voltage. When the C/20 rate is reached, the current should be held constant until the batteries reach 2.6 VPC. The batteries should be equalized at least once every 10 cycles or 10 days by holding the voltage at 2.6 VPC for two hours at the end of a complete charge.

The City-el Charger regularly holds these batteries at 2.65 VPC for as long as 5 hours before entering the float charge at lower voltage and about 0.4 Amps. With the City-el charger, the gassing period is varied based on the time to complete the main charge, and on the charge history of the vehicle, ie: was the last charge interrupted. There is no doubt the City-el charger is set up to over equalize the Trojan batteries compared to the Trojan specification.

The PEPCO charger as initially configured is undercharging the batteries somewhat based on specific gravity readings. It would appear to be advisable to increase the equalizing period from about 1 hour to about 2

hours at the finish rate of 4 - 5 Amps. This would provide a charge which is in accordance with Trojan's specification, and should therefore result in specific gravity readings within Trojan's specification.

Conclusions:

The PEPCO TURBO-Z charger is a very good pulse charger, which is capable of halving the time to charge a City-el battery pack. The TURBO-Z as tested is essentially in it's first configuration for charging Trojan 30XH 12 Volt batteries, and can be adjusted further to match the battery manufacturer's specification. The TURBO-Z provided a near full charge to the pack from a half discharged condition (900 W-h DC) in 1.5 hours, compared to about 4 hours for the City-el charger to the same point. The TURBO-Z charged the City-el pack from a complete discharge (1800 W-h) in 4.5 hours compared to a City-el charge taking about 10 hours to about the same state of charge.

The TURBO-Z did not appear to heat the batteries as much as the City-el charger does during charging. The TURBO-Z is about 75% efficient in delivery of energy to the battery pack, as opposed to about 61% for the City-el charger without undue float charge duration.

Use of the TURBO-Z to charge City-els would decrease the total energy use of the vehicles. The composite energy use for the 4 discharge-charge cycles discussed in this report is 235 AC W-h/ mile, compared to our fleet average of greater than 500 AC W-h/mile. As presently configured, the TURBO-Z could be used for "opportunity charges" to increase the daily range capability of the vehicle, providing the City-el charger was used once every 10 cycles to equalize the batteries.

The TURBO-Z could be modified to lengthen the finish charge portion of the cycles to 2 to 3 hours, and then should be used exclusively to charge a vehicle for an extended time period. Use of the TURBO-Z exclusively should result in a total energy use of around 150 W-h/mile, given that the Trojan specification for a longer time period in the equalizing phase was followed.

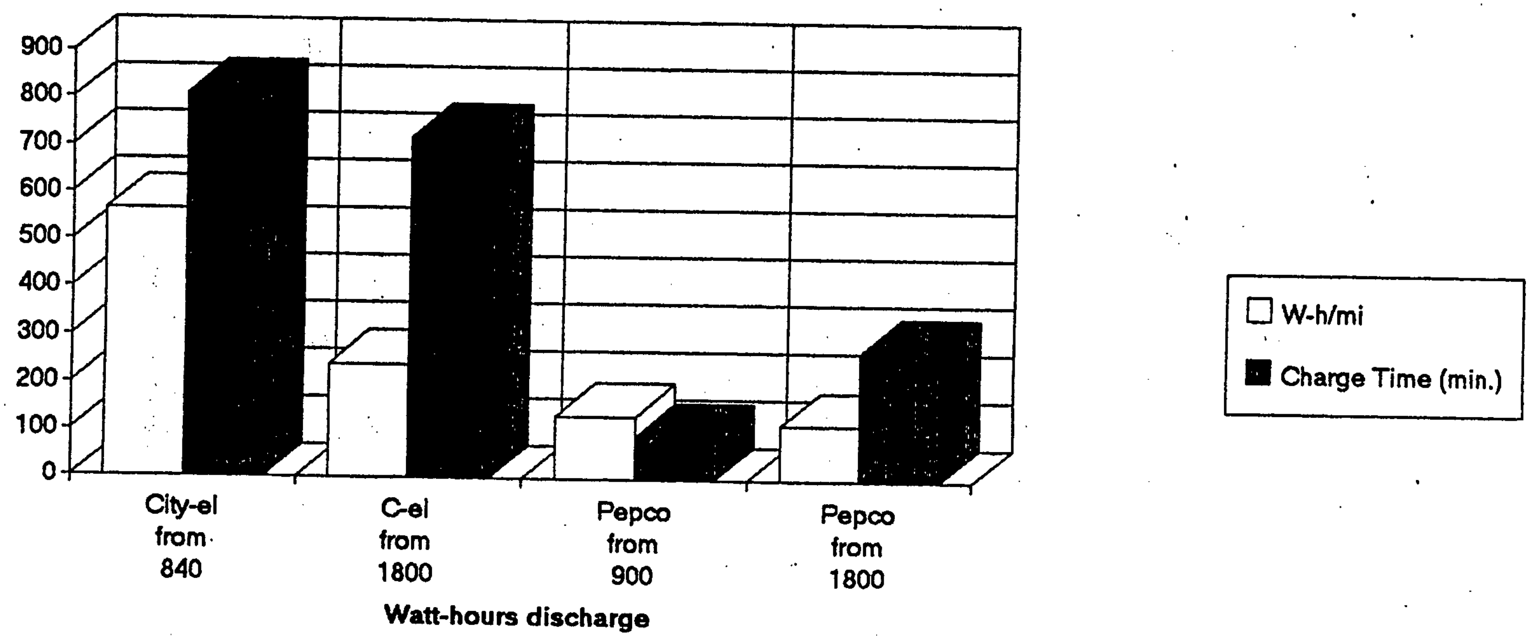
List of Appendices:

Appendix:

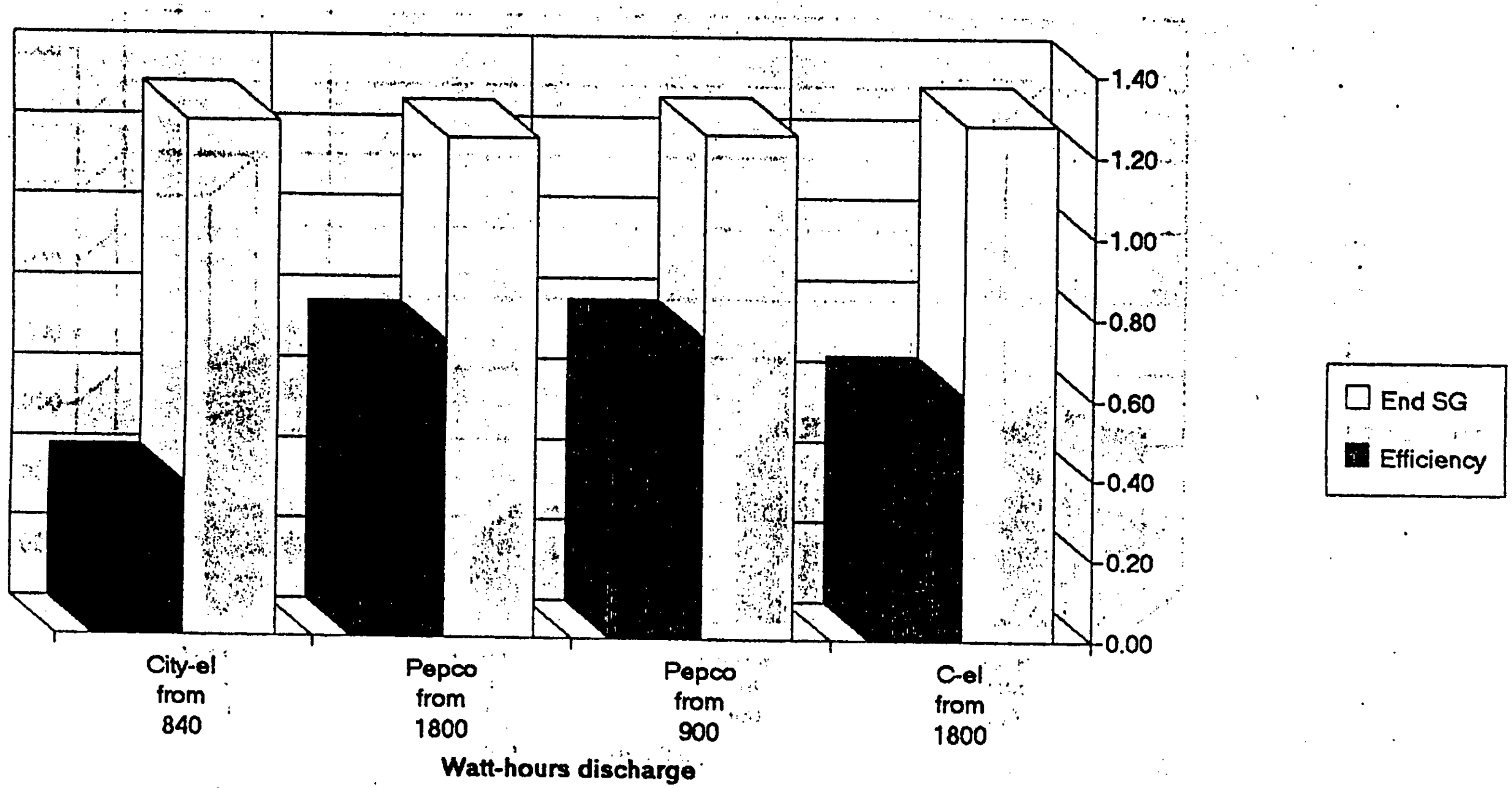
1. Trojan Charging Specification
2. Summary of Tests, Table "Pepsum.XLS"
3. Battery Characterization Data sheets
4. City-el DAS Data, Trip and Charge on 12/14/94, and trip 12/15 AM
5. Data and charts, TURBO-Z charge from 900 DC W-h Discharge
6. City-el DAS Data, Trip on 12/15/94, PM
7. Data and charts, TURBO-Z from 1800 DC W-h Discharge
8. City-el Charge on 12/16/94
9. DAS BIN listing

EVENT	Distance	DC Energy	AC Energy	Efficiency	Time	End SG	End V	w-h/mi.		overcharge
	(meters)	(W-h)	(W-h)	(%, DC/AC)	(min)		(Volts)			
Trip 12/14	39866	-1800	0		70	1.160	36.5	-72.82	DC	
Charge 12/14	0	3650	5958	61%	720	1.280	39	241.05	AC	2.03
Trip 12/15 AM	17571	-900	0		32	1.235	38	-82.61	DC	
Charge 12/15 AM	0	1100	1469	75%	92	1.250	40	134.84	AC	1.22
Trip 12/15 PM	43884	-1800	0		74	1.160	36.5	-66.16	DC	
Charge 12/15 PM	0	2360	3194	74%	273	1.240	40.5	117.39	AC	1.31
Trip 12/16 AM	20323	-840	0		32	1.225	38	-66.67	DC	
Charge 12/16 PM	0	2710	7126	38%	810	1.280	39	565.54	AC	3.23
Totals	121644		17747					235.31		

The City-el Charger takes much more time in charging, and yields higher AC energy use per mile



The City-el Charger is less efficient, but provides a 1.28 SG finish while the Turbo-Z stopped at 1.24-1.25 SG



City-el
Data Acquisition System
User's Manual

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City-el Data Acquisition System User's Manual
Table of Contents

City-el Data Acquisition System (DAS)
User's Manual

What Is the DAS?

The DAS is a microprocessor based data acquisition system for the City-el vehicle. This system takes second by second vehicle performance data. Data averages are stored in performance bins for later retrieval. The system will store up to 40 trips and 25 charges. If the data is not downloaded before the maximum capacities are reached, new data overwrites the oldest data. The following information describes how to connect to and operate the DAS.

Hardware Connection

Equipment Needed: DB-9F to DB-9F cable with straight through wiring.
PC computer (notebook preferred).

To communicate with the DAS, it is necessary to connect the male DB-9 connector of the DAS to the computer serial port. In most cases, the computer port is also a male DB-9 connector. This means that you need a female DB-9 to female DB-9 cable. This cable should be wired straight through meaning that pin 1 is wired to pin 1 and pin 2 is wired to pin 2, etc.

Software Connection

Software Needed: Communications software package (Windows Terminal works fine).

The communications parameters to be set in the communications software are listed below. Windows Terminal settings for each choice are also listed. The Windows Terminal settings can be found under the Settings menu in the Communications dialog box. None of the other settings need to be adjusted.

PARAMETER	SETTING	WINDOWS TERMINAL
BAUD RATE:	9600	9600
PARITY:	NONE	Uncheck Parity box
DATA BITS:	8	8
STOP BITS:	1	1
HANDSHAKE:	HARDWARE	Listed as Flow Control
DUPLEX:	FULL	Not listed

Once these settings have been made, verify connection to the DAS by simply pressing enter a few times. The screen should respond with a "?" and a prompt indicating the DAS operating mode.

CAUTION: If the software settings are incorrect, the DAS will lockup. There will be no prompt and perhaps some junk on the screen. If this happens the DAS must be unplugged from the DB-25 connector and then reconnected in order to reset it. The data and calibration data will still be intact because they are stored in nonvolatile memory. Consider this process to be the same as rebooting a computer.

DAS Naming Convention

The files that are downloaded from the DAS must be named using the following convention.

File Name Pattern: D*NNNYDDD*.1*AX*

"D" First letter for the coalition designation is "D"

"*NNN*" Next 3 digits are last 3 digits of the vehicle VIN#.

"*YDDD*" Next 4 digits are the Julian date of the download. The first number is the last digit of the year. For 1994, the number would be 4. The year is followed by the number of the day since January 1st which is day 001. January 5th would be 005. February 2nd would be 033. It continues in this way until December 31st which is day 365 except for leap years.

"1" First digit in the extension is the trip number which is "1". In the case of multiple monitored charges or trips in a single day this number should be incremented by one for each charge or trip.

"*A*" The second position in the extension is the file type designation. Use "S" for statistical data which is the case when downloading the DAS. For monitored trips or charges where data was collected second by second with the computer, the letter is "T" for time series data. See the section titled "Collecting Data by Monitoring the DAS" for more information on how to collect second by second data with the computer.

"*X*" The last position is Pacific EV's informational letter.
"D" is used for a successful and normal download of the DAS.
"E" is used when a download was performed with the ERROR prompt showing. See "The ERROR> Prompt" section for more information.
"P" is used for the download made immediately after calibration and testing of the DAS.
"H" is used when the DAS is locked up and must be disconnected and reconnected before the DAS can be downloaded.
"R" is used when monitoring a run with the computer.
"C" is used when monitoring a charge with the computer.

Example 1: For City-el 3994 successfully downloaded on June 15, 1994, the filename would be:
D9944166.1SD

Example 2: For City-el 4126 downloaded on October 20, 1994 while the DAS was showing the ERROR prompt, the filename would be:
D1264293.1SE

Example 3: For a charge monitored with the computer on City-el 4135 on June 9, 1995, the filename would be:
D1355160.1TC

Downloading a Data File

Items Needed: Proper Data File Name
Data Diskette

After the connection to the DAS has been made, the downloading of the data can begin. First prepare the communications software to receive an ASCII text file. For the Windows Terminal, this is found under the Transfers menu in the Receive Text File dialog box. Pick an appropriate drive letter, and name the file using the proper naming convention. Refer to the "DAS Naming Convention" section for naming details. Finally, click OK. When you are back at the DAS idle> prompt, press "d" for download. The data stored in the DAS will scroll down the screen as the data file is made. After the DAS prompt has returned, close the data file. For the Windows Terminal, this requires that the STOP button in the lower left corner be clicked.

Readying the DAS to Collect Data Again

After verifying that the downloaded data was written properly to disk, the DAS can be zeroed. Press "z" to clear the existing data from the DAS. You may now exit the communications software and disconnect the computer from the DAS.

The ERROR> Prompt

This prompt indicates that the DAS had some sort of fatal software during the collection period. There is still data to collect from the DAS! The data should offer some clues as to the type of error. Use the ERROR naming convention described in the "DAS Naming Convention" section to name the file. Collect the data as usual and zero the DAS. The zero and reset commands will correct the prompt. DO NOT USE RESET UNLESS YOU WANT TO RECALIBRATE THE DAS.

Collecting Data by Monitoring the DAS

The DAS collects data in a time series manner 200 times a second but stores the data as statistical data in performance bins. A typical download of the DAS therefore contains data stored in bins defined by a speed range and an acceleration range or in the case of a charge, the data is stored in hourly average bins. See the Appendix for a complete description of the DAS Data Format. Although the DAS stores only statistical data, it is possible to obtain second by second time series data from the DAS. This is done by monitoring the DAS with a laptop computer. This process is described below.

Monitoring a Charge: Hookup the computer to the DAS as described previously and bring up the idle> prompt. Setup the communications software to receive a text file. Use the file naming convention described previously. Plug in the charger. Press ENTER if necessary to bring up the charge> prompt. Press "m" for monitor and enter the desired number of seconds between displayed averages. Valid values are from 01 to 99.

Monitoring a Run: Hookup the computer to the DAS as described previously and bring up the idle> prompt. Setup the communications software to receive a text file. Use the file naming convention described previously. Turn on the key and press ENTER if necessary to bring up the run mode. Press "m" for monitor. In many cases the DAS will immediately start taking data from the instant the key was turned on. When monitoring a run, data is given every second.

IMPORTANT: Place the laptop computer on the floorboard of the City-el. This is the only location that is relatively free from electro-magnetic noise created by the charge transformer, motor, amplifier, and other components. Secure the laptop as necessary when monitoring a run so that it does not interfere with the pedals.

Calibration and Setup

Equipment Needed:	DB-9F to DB-9F cable with straight through wiring.
	PC Computer (notebook preferred)
	Communications software package
	Voltmeter
	MiliVoltmeter
	City-el Diagnosis Box

The setup procedure is used to set the main and charge shunt values, the number of watt-hours per tick of the AC watt-hour meter, and the number of meters per tick of the speedometer sensor. In addition, the vehicle ID number and the date and time are set. Generally, setup will only be used to correct the date and time. All other values will be entered as is.

The calibration procedure first asks for the first 4 setup items and then asks for the calibration data and finally asks for the last 3 setup items. This procedure MUST be done

after initial installation of the DAS and after any major changes to the vehicle like different batteries or motors. The calibration procedure follows.

IMPORTANT: It is impossible to press Backspace to correct entry errors. You must start the Setup or Calibration procedure over to correct entry errors. To start over, either press ENTER until the idle> prompt returns or unplug the DB-25 plug from the DAS. In some cases pressing ENTER repeatedly to return to the idle> prompt will cause the ERROR> prompt to display. Press "r" to reset the DAS and remove the ERROR> prompt. Start the Calibration procedure over.

1. Plug in City-el Diagnosis Box, or see Appendix for Diagnosis Plug Pin Outs.

2. Connect computer to DAS. Refer to the "Hardware Connection" and "Software Connection" sections for instructions.

3. Issue the (C)alibrate command and respond with a "y" for yes.

4. "main V/A" Enter the main shunt value of 0.000333 volts/amp and press ENTER.

5. "charge V/A" Enter the charge shunt value of 0.003333 volts /amp and press ENTER

6. "wh/tick" Enter the watt-hours for each tick of the Hydria meter and press ENTER. Currently, this appears to be about 0.9 Wh per tick.

7. "vin#" Enter the 4 character VIN number. The numbers will not display on the screen until after they are entered. **Do not press ENTER.**

8. "V=?" Enter the battery voltage as measured at the diagnosis box connectors and press ENTER. The DAS will respond with the measured voltage.

9. "main=0?" Press ENTER when the key is off.

10. "main=?" Enter the mV reading across the main shunt as measured at the diagnosis box connectors and then press ENTER. This must be done while the vehicle is stalled with the accelerator to the floor. To stall the vehicle, the canopy safety switch on the right side must be depressed. Set the parking brake; step on the brakes; and then floor the accelerator. The milivolt reading must be entered into the computer while the vehicle is in this state. The reading MUST be entered in volts. Typically the reading is around 20 mV so a decimal and a zero must precede the 20. (i.e. 0.020) It is very helpful to enter the decimal and the zero before stalling the vehicle because the reading falls rather rapidly. The DAS will respond after the reading is entered with the measured stall current. This will typically be around 60 amps. This part of the calibration is critical because it sets how the DAS measures the energy used by the vehicle during the driving cycle. Try to get it as accurate as possible.

11. "charge=0?" Press ENTER when the charger is not plugged in and the key is off.

12. "charge=?" Enter the mV reading across the charge shunt as measured at the diagnosis box connectors and press ENTER. Plug in the charger and let it stabilize before entering the mV reading. This MUST be entered in volts. The reading will typically be around 40 mV so it would be entered as 0.0401 for example. The DAS will respond with the measured current. Typically this will be around 11 amps. Since this sets the measured current during the charge, it is important to get this as accurate as possible.

13. "m/tick" Enter the number of meters for each tick of the speed sensor and press ENTER. Currently this is 0.403.

14. (hh:mm:ss) Enter the current time in 24 hour format. Only the digits need to be entered but include leading zeros. The DAS will respond with the colons at the right time. Do not press ENTER.

15. (mm/dd/yy) Enter the current date. Only the digits need to be entered but include leading zeros. The DAS will respond with the slash at the right time. Do not press ENTER.

Testing

Once the DAS has been Calibrated, it should be tested. This involves monitoring a charge and a run to determine whether the values that are being recorded by the DAS are correct.

Testing a Charge. Setup the computer to monitor a charge as described in the Collecting Data by Monitoring the DAS section. Choose 1 second intervals. Verify that the temperature is reasonable. Keep in mind that this is battery temperature and may be slightly different than the ambient temperature. Verify that the AC watt-hour counter only counts after the Hydria meter counter on the transformer has clicked. Check that the current and voltage are reasonable. Typically the charger current will be between 9 and 12 amps and the voltage will be between 37 and 45 volts. The current and voltage values can also be checked against a multimeter plugged into the Diagnosis box. See the Appendix for the Diagnosis Plug Pin Outs.

Testing a Run. Setup the computer to monitor a run as described in the Collecting Data by Monitoring the DAS section. Jack up the rear of the vehicle. Depress the canopy safety switch. Turn on the vehicle, release the parking brake, and switch to forward. Verify that the voltage and current are reasonable or check them against a multimeter plugged into the diagnosis plug. See the Appendix for the Diagnosis Plug Pin Outs. Check that the speed changes smoothly and check that it stays stable at a constant wheel speed.

Calibration and Testing Download. Immediately after finishing the calibration and testing procedure, download the DAS using the proper naming convention including the "P" informational letter at the end of the file name. This download serves two purposes. First, it provides a record of the calibration values and proof that the calibration was done correctly. Second, it provides the date and time of the new calibration.

Trouble Shooting

There is only a blinking cursor on the screen.
In most cases just hit ENTER to bring up the prompt. In some cases, the DAS may be locked up. To "Reboot" the DAS disconnect the DB-25 connector from the back of the box for a few seconds and then reconnect the DB-25 connector. Make sure that the communications software settings are correct and then hit ENTER. Data and calibration settings are not lost during this procedure because they are stored in nonvolatile RAM.

The DAS shows the Charge prompt even with the charger unplugged.
In some cases, after hooking up to the DAS, the charge> prompt will show even though the charger is not plugged in. This is because the charge light on the dash is still showing. This light stays on until the first time the key is turned on after a charge. Turning the key on and then off will bring back the idle> prompt.

I made an entry error during calibration and can't backspace to fix the error.
It is impossible to press Backspace to correct entry errors. You must start the Setup or Calibration procedure over to correct entry errors. To start over, either press ENTER until the idle> prompt returns or unplug the DB-25 plug from the DAS. In some cases pressing ENTER repeatedly to return to the idle> prompt will cause the ERROR> prompt to display. Press "r" to reset the DAS and remove the ERROR> prompt. Start the Calibration procedure over.

The VIN numbers are not displaying during the setup procedure.
The numbers will not display on the screen until after they are entered. Enter all 4 digits and then they will display.

Some of the letters are missing from the prompt or from the setup and calibration questions
Occasionally some of the letters get lost during the transmission from the DAS to the computer. Generally everything will still work properly.

I Calibrated the DAS but there are negative numbers while monitoring the charge.
It is necessary to hit ENTER to bring up the charge> prompt and then press "m" for monitor after calibrating the DAS. If this is not done, the new calibration numbers are not used for the information being displayed.

Appendix

DAS Command Summary

(D) ownload -	Sends all stored trips and charges out the serial cable in ASCII format. Use this command after preparing the computer for ASCII file retrieval. Once the data has been transferred successfully, close computer file and (Z)ero DAS.
(Z) ero -	Zeros the data buffer on the DAS and prepares the system for a new batch of data collection. DO NOT ZERO THE SYSTEM UNTIL YOU ARE SURE THAT YOU HAVE COLLECTED THE DATA!!!!
(R) eset -	Changes all setup data to the default values. DO NOT USE UNLESS YOU WISH TO LOSE THE CALIBRATION DATA!!!
(S) etup -	Asks the user for the setup data listed below:

"main V/A"	Shunt value 0.000333. Press ENTER.
"charge V/A"	Shunt value 0.003333. Press ENTER.
"wh/tick"	Enter sensor value of 0.9. Press ENTER.
"vin#"	Enter 4 character VIN. **Don't press ENTER.**
"m/tick"	Enter speed sensor value of 0.403. Press ENTER.
(hh:mm:ss)	Enter time digits only. **Don't press ENTER.**
(mm/dd/yy)	Enter date digits only. **Don't press ENTER.**

(C) alibrate - Asks the user for setup data as well as the following additional questions to aid in self calibration. DO NOT USE UNLESS YOU WISH TO RE-CALIBRATE DAS!!

"V=?"	Enter battery pack voltage. Press ENTER.
"main=0?"	Press ENTER when key is off.
"main=?"	Enter mV reading across main shunt when vehicle is stalled with accelerator depressed. Enter the reading in volts not mV. Press ENTER.
"charge=0?"	Press ENTER when charger is off.
"charge=?"	Enter mV reading across charge shunt once charger has stabilized. Enter reading in volts not mV. Press ENTER.

(M) onitor - Sends data collected for each second out the serial cable while running and prompts for averaging interval during charge. Valid numbers are from 1 to 99 seconds.

DAS Modes of Operation

run> prompt	Defined by key on and charger off. Commands available: (M)onitor
charge> prompt	Defined by charger light on. Commands available: (M)onitor
idle> prompt	Defined by key off and charger off Commands available: (R)eset, (Z)ero, (C)alibrate, (D)ownload, (S)etup
ERROR> prompt	Indicates that a fatal software error has occurred at some point during the collection period. Commands available: (D)ownload, (Z)ero, (R)eset, (C)alibrate, (S)etup

DAS Data Format.

DAS Download File Format. The pages A5 and A6 contain a shortened sample of a DAS download file. Refer to these pages as necessary during the descriptions that follow. Each data file has 3 main parts. First, there is a header record that contains data on the vehicle, the download date, and the calibration data. Second, there is a list of trips from 1 to as many as 40, and finally, there is a list of charges from 1 to as many as 25.

Before the header record there will always be a "d". During the downloading procedure the terminal software records the "d" command that is used to start the download of the DAS. The header record starts by giving the number of trips and charges contained in the file. It then gives the vehicle ID number and the date and time of the download. This information is followed by some of the calibration values.

Each trip begins with the trip number. This number is the sequential number of the trip since the DAS was last zeroed. The DAS then records the starting date and time of the trip as well as the total distance traveled in meters, the starting battery temperature in degrees Celsius, and the total DC watt-hours used. Time is in 24 hour format, and Battery temperature is sampled only once at the beginning of the trip. The watt-hours are computed by multiplying the average voltage and current for each second. This gives watt-seconds. All of the watt-seconds are summed during the entire trip to give the total watt-seconds used during the entire trip. At the end of the trip this number is converted to watt-hours and stored. The remainder of the trip data is the bin data. Each bin is defined by a speed and acceleration range. See the table below for the bin definitions for each bin. A single bin contains the total number of seconds spent in that bin in addition to the average speed, acceleration, voltage, and current seen during the time spent in the bin. The speed is measured in meters per second (m/s) while the acceleration is measured in meters per second per second (m/s^2). Voltage is in volts, and current is in amps.

DAS Trip Bin Definitions.

Bin #	0	<5	<10	<15	<20	<25	>25	m/s
>2.5		1	8					
>1.5		2	9	15	21			
>0.5		3	10	16	22	26	29	
0	32	4	11	17	23	27	30	
<-0.5		5	12	18	24	28	31	
<-1.5		6	13	19	25			
<-2.5		7	14	20				
m/s^2								

Each charge begins with a charge number. This charge number is the sequential number of the charge since the DAS was last zeroed. This is followed by the starting time and date of the charge. Note that the time is in 24 hour format. The total number of seconds during the charge is recorded. This number is really only good for telling the number of seconds up to the 12th hour. Beyond about 65,000 seconds, the counter will reset and start counting from zero again. The total number of AC watt-hours used during the charging process is also stored. This number extends beyond the 12 hour data period. Both the seconds counter and the AC watt-hours counter continue counting until the key is turned on with the charger unplugged. The rest of the charge data is the average AC watts, battery pack voltage in volts, charge current in amps, and battery temperature in degrees Celsius for each hour of the charge up to 12 hours. Generally the 12th hour of data can not be used. The software in the DAS has a problem averaging this last hour of data.

DAS Monitored Charge File. Page A7 contains the first part of a second by second monitored charge. Refer to this page as necessary. When monitoring a charge, there is no header for the file or other means of identification. For this reason, it is very important to use the correct DAS naming convention. The column titles have been added to this file as descriptions and do not appear in the real file. Each second of data contains the current number of AC watt-hours used, the current battery temperature in degrees Celsius, the battery pack voltage, and the charging current. Notice that the first second has strange data. This is typical even when monitoring by intervals other than second by second. Accuracy is fairly good for all quantities except the charge current. Because of the calibration method, the charge current can vary from the actual by as much as 3 amps. It is recommended that the charge shunt be measured periodically throughout the monitoring process in order to quantify the exact amount of error. Since the amount of error tends to change as the charging current drops, the periodic checking is necessary.

DAS Monitored Run File. Page A8 contains a section of a second by second monitored run. There are no headers for the monitored run files so it is important to use the correct DAS naming convention. A title row has been added to the example file for informational purposes and does not appear in regular files. A monitored run contains the vehicle speed in meters per second, the battery pack voltage, the battery pack current, and the battery temperature in degrees Celsius. All quantities are pretty accurate except for the battery current which may deviate from the actual current by 30 amps in the 120 amp region. The amount of error seems to decrease at lower current draws and may be off by only several amps in the 60 amp region. In order to have accurate data, the main shunt should be monitored with a multimeter and compared to the DAS data. This should be done over a wide range of currents since the amount of error changes depending on the current being drawn.

Example DAS Downloaded Data File

Description	DAS Data File					
DAS download command.	d					
Number of Trips currently stored in DAS.	trips	4				
Number of Charges stored in DAS.	charges	13				
City-el ID number.	vin	4135				
Download Time in 24 hour format.	16:08:02					
Download Date.	12-13-94					
Watt-hours per tick of Hydria meter.	wh/tick	0.9				
Meters per tick of speed sensor.	m/tick	0.4				
Calibration number for Key off.	main off	-0.2				
Main shunt number for Volts per bit.	main V/bit	3.53E-05				
Calibration number for charger off.	charge off	63.84				
Charge shunt number for Volts per bit.	charge V/bit	-2.81E-05				
Battery voltage number for Volts per bit.	batt V/bit	2.57E-02				
Trip number.	trip#	1				
Trip start time.	10:34:59					
Trip date.	12-8-94					
Trip distance	meters	22696.85				
Trip starting temperature in Celsius.	Temp	13.03				
DC Watt-hours used during trip.	Wh	1058.02				
Trip data title bar.	bin	sec	m/s	m/s^2	Volts	Amps
Bin 1 data.	1	0	0	0	0	0
Bin 2 data.	2	1	1.86	1.58	33.21	123.99
Bin 3 data.	3	43	2.86	0.86	34.01	93.32
etc.	4	38	1.77	0.05	35.88	15.57
	5	24	1.89	-0.97	36.2	5.28
	6	9	3.58	-1.71	35.96	5.29
	7	0	0	0	0	0
	8	0	0	0	0	0
	9	0	0	0	0	0
	10	34	6.94	0.67	33.1	129.95
	11	139	8.44	0.19	34.07	64.69
	12	19	7.86	-1.06	35.81	5.46
	13	13	7.35	-2.01	35.89	5.61
	14	1	5.76	-2.63	36.5	4.89
	15	0	0	0	0	0
	16	0	0	0	0	0
	17	1648	12.51	0.01	34.41	55.82
	18	12	11.19	-0.82	35.92	5.14
	19	1	11.21	-1.72	35.9	5.68
	20	0	0	0	0	0
	21	0	0	0	0	0
	22	0	0	0	0	0
	23	0	0	0	0	0
	24	0	0	0	0	0
	25	0	0	0	0	0
	26	0	0	0	0	0
	27	0	0	0	0	0

		28	0	0	0	0	0
		29	0	0	0	0	0
		30	0	0	0	0	0
		31	0	0	0	0	0
Bin 32 Data		32	136	0	0	36.3	5.29
Other data.	...						
Charge number.	charge#		11				
Charge start time.	15:08:15						
Charge start date.	12-9-94						
Total number of seconds of charge.	seconds		13263				
AC Watt-hours put in during charge.	Wh		3914				
Charge data title bar.	hour		AC W	volt	amp	degC	
First hour averages.		1	785	39.95	11.51	15.77	
Second hour averages.		2	758	41.99	10.7	16.48	
Third hour averages.		3	407	47.9	4.81	17.27	
etc.		4	324	49.08	3.68	18.37	
		5	320	49.14	3.6	19.48	
		6	318	49.09	3.58	20.33	
		7	317	49.06	3.57	20.88	
		8	90	42.02	0.79	20.63	
		9	54	40.75	0.32	18.77	
		10	54	40.94	0.3	16.82	
		11	54	41.1	0.28	15.05	
		12	39	40.87	0.15	9.15	
	charge#		12				
	16:32:38						
	12-10-94						
	seconds		33919				
	Wh		7569				
	hour		AC W	volt	amp	degC	
		1	762	38.38	11.63	16.69	
		2	798	39.29	11.52	16.86	
		3	775	40.18	11.2	17.02	
		4	768	41.8	10.9	17.06	
		5	550	45.69	7.09	17.63	
		6	387	48.01	4.65	18.62	
		7	351	48.51	4.1	19.84	
		8	341	48.66	3.91	20.94	
		9	333	48.71	3.84	21.73	
		10	329	48.72	3.78	22.3	
		11	326	48.72	3.75	22.72	
Note voltage problem with 12th hour.		12	110	86.37	0.59	26.14	
Charge 13 omitted.	...						
DAS idle prompt after finishing download.	idle[(R)eset,(Z)ero,(C)alibrate,(D)ownload,(S)etup]>						

Example of DAS Monitored Charge File

AC Watt-hours	Temperature	Voltage	Current
0.9 Wh	80.1 deg C	4.15 V	0.3 A
0.9 Wh	13.1 deg C	37.58 V	0 A
0.9 Wh	13.1 deg C	37.58 V	0 A
0.9 Wh	13.1 deg C	37.58 V	0 A
0.9 Wh	13.1 deg C	37.58 V	0 A
0.9 Wh	13.1 deg C	37.58 V	0.1 A
0.9 Wh	13.1 deg C	37.64 V	1 A
0.9 Wh	13.1 deg C	37.82 V	3.1 A
0.9 Wh	13.1 deg C	38.12 V	6.5 A
0.9 Wh	13.1 deg C	38.45 V	9.6 A
0.9 Wh	13.1 deg C	38.69 V	11.4 A
0.9 Wh	13.1 deg C	38.79 V	11.6 A
1.8 Wh	13.1 deg C	38.86 V	11.5 A
1.8 Wh	13.1 deg C	38.9 V	11.7 A
1.8 Wh	13.1 deg C	38.97 V	11.7 A
1.8 Wh	13.1 deg C	39.03 V	11.5 A
1.8 Wh	13.1 deg C	39.08 V	11.7 A
2.7 Wh	13.1 deg C	39.13 V	11.6 A
2.7 Wh	13.1 deg C	39.19 V	11.5 A
2.7 Wh	13.1 deg C	39.24 V	11.6 A
2.7 Wh	13.1 deg C	39.3 V	11.4 A
2.7 Wh	13.1 deg C	39.34 V	11.6 A
3.6 Wh	13.1 deg C	39.39 V	11.4 A
3.6 Wh	13.1 deg C	39.44 V	11.5 A
3.6 Wh	13.1 deg C	39.49 V	11.5 A
3.6 Wh	13.1 deg C	39.54 V	11.4 A
3.6 Wh	13.1 deg C	39.58 V	11.5 A
4.5 Wh	13.1 deg C	39.64 V	11.4 A
4.5 Wh	13.1 deg C	39.68 V	11.6 A
4.5 Wh	13.1 deg C	39.73 V	11.3 A
4.5 Wh	13.1 deg C	39.78 V	11.5 A
5.4 Wh	13.1 deg C	39.83 V	11.2 A
5.4 Wh	13.1 deg C	39.88 V	11.5 A
5.4 Wh	13.1 deg C	39.92 V	11.3 A
5.4 Wh	13 deg C	39.97 V	11.4 A
5.4 Wh	13 deg C	40.01 V	11.4 A
6.3 Wh	13.1 deg C	40.07 V	11.2 A
6.3 Wh	13 deg C	40.12 V	11.5 A
6.3 Wh	13 deg C	40.16 V	11.3 A
6.3 Wh	13 deg C	40.21 V	11.3 A
6.3 Wh	13 deg C	40.26 V	11.5 A
7.2 Wh	13 deg C	40.3 V	11.1 A
7.2 Wh	13 deg C	40.31 V	11.3 A
7.2 Wh	13 deg C	40.32 V	11 A
7.2 Wh	13 deg C	40.39 V	11 A
7.2 Wh	13 deg C	40.43 V	11.2 A
8.1 Wh	13 deg C	40.48 V	10.9 A
8.1 Wh	13 deg C	40.52 V	11.3 A

Example of DAS Monitored Run File

Speed: meters/sec.	Voltage	Current	Temperature
0 m/s	38.6 V	0.4 A	21 deg C
0 m/s	37.95 V	17.5 A	21 deg C
1.2 m/s	35.31 V	89.9 A	21.1 deg C
2.4 m/s	34.05 V	129.3 A	21 deg C
3.8 m/s	33.24 V	154.8 A	21 deg C
5 m/s	33.18 V	153.5 A	21.1 deg C
5.9 m/s	33.17 V	151.6 A	21.1 deg C
6.8 m/s	33.2 V	148.9 A	21.1 deg C
7.5 m/s	33.18 V	148 A	21.1 deg C
8.2 m/s	33.45 V	135.9 A	21.1 deg C
8.7 m/s	33.8 V	121.7 A	21.1 deg C
9.1 m/s	34.07 V	111.4 A	21.1 deg C
9.4 m/s	34.27 V	104.1 A	21.1 deg C
9.7 m/s	34.45 V	97.8 A	21.1 deg C
9.9 m/s	34.6 V	92.3 A	21.1 deg C
10.2 m/s	34.7 V	88.7 A	21.1 deg C
10.3 m/s	34.8 V	85.6 A	21 deg C
10.4 m/s	34.86 V	83.6 A	21.1 deg C
10.6 m/s	34.92 V	81.4 A	21.1 deg C
10.8 m/s	35 V	79 A	21.1 deg C
10.8 m/s	35.04 V	77.7 A	21.1 deg C
10.9 m/s	35.09 V	75.9 A	21.1 deg C
11 m/s	35.13 V	74.6 A	21.1 deg C
11.2 m/s	35.16 V	73.3 A	21.1 deg C
11.2 m/s	35.21 V	71.6 A	21.1 deg C
11.3 m/s	35.23 V	70.9 A	21.1 deg C
11.4 m/s	35.27 V	69.8 A	21.1 deg C
11.5 m/s	35.32 V	67.9 A	21.1 deg C
11.6 m/s	35.36 V	66.8 A	21.1 deg C
11.8 m/s	35.39 V	65.5 A	21.1 deg C
11.9 m/s	35.42 V	64.7 A	21.1 deg C
11.9 m/s	35.45 V	63.9 A	21.1 deg C
11.9 m/s	35.48 V	63.2 A	21 deg C
12 m/s	35.48 V	62.8 A	21.1 deg C
12.1 m/s	35.51 V	62.2 A	21 deg C
12.1 m/s	35.51 V	61.8 A	21 deg C

Diagnosis Plug Pin Outs

The Diagnosis Plug is located on the panel under the front of the seat bottom. This 15 pin plug is designed to be used with the City-el Diagnosis box but can be used with a multimeter if necessary. The following pin outs describe what data can be obtained using a multimeter. Careful examination of the back side of the plug will reveal the pin numbers molded into the plug. Furthermore, pin 3 is longer than any of the other pins. Use extreme caution when jumping across these pins with a multimeter. It is possible to blow fuses or otherwise damage the electronics in the City-el.

Pin 1: Battery positive terminal 28 to 48 volts.
Pin 2: DC to DC converter positive terminal 11.5 to 13 volts.
Pin 3: Ground.

Pin 4: not used.
Pin 5: Speed sensor. 0 volts normally. 12 volts each time a magnet passes the sensor.
Pin 6: Charger Error light. Off: 5mV On:?

Pin 7: Negative side of Charge Shunt.
Pin 8: Positive side of Charge Shunt.
Pin 9: Charger 100% light. Off: 11 volts On: 14mV

Pin 10: Charger 82% light. Off: 11 volts On: 14mV
Pin 11: Charger on signal. Off: 36 volts On: 40mV
Pin 12: Charger extra gassing light. Off: 2mV On: 7mV

Pin 13: Positive side of Main Shunt.
Pin 14: Negative side of Main Shunt.
Pin 15: not used.

Front view of Diagnosis Plug

13	14	15
10	11	12
7	8	9
4	5	6
1	2	3

NOTES:

City-el Inspection and Service Report Sheet Instructions.

City-el Inspection Report Sheet. This sheet is used for recording the manual monthly data. Most of the fields are self explanatory. For the "Start DAS download procedure:" field put in the name of the DAS download file. For the "Dots:" field record the number of dots on the capacity gage. The "State of Charge %:," "12 Volt Light:," and the "ETG Light:" fields are taken from the City-el Diagnosis Box. If a diagnosis box is not available ignore these fields. The most important data on this sheet is the VIN number, the Date, the Kilo-Watt hour meter reading, and the Odometer Reading. This data MUST be given on every data sheet.

City-el Service Report Sheet. This sheet is used for work done on the City-el at times other than the monthly service. If no parts were used ignore the Parts Used section. These sheets should be kept and submitted with the next monthly data sheet. **Although it is not listed, the Kilo-Watt hour meter reading MUST be recorded when ever the service involves changing the batteries, the charger board, or the transformer.**

City-el Inspection Report **Neighborhood Electric Vehicle Program**

VIN = ______________________
Date = ______________________
Inspection by = ______________________

Start DAS download procedure: __________
Kilo-Watt hour meter reading = ______________________
Odometer Reading = ______________________

Tires / Wheels	Pressure (as Found)	Tire Wear	Wheel Condition
Front:	(35 psi)__________	__________	______________
Left Rear:	(37-40)__________	__________	______________
Right Rear:	(37-40)__________	__________	______________

Jack up front of vehicle and check play in front wheel: ______________________
Clean and Lubricate Clutch Disc: ______________________

Batteries (if batteries appear nearly full check specific gravity.)
Water Added (in Liters): __________ Left Battery: ______________
Battery Appearance: ______________ Center Battery: ______________
Battery Type: ______________________ Right Battery: ______________

Complete DAS Download: __________

Diagnosis Box
Voltage: __________ State of Charge %: 82% 100%
Dots: ______________ 12 Volt Light: Yes No ETG Light: Yes No

Chassis Checks
Body Condition: ____
Lights Operation: ____
Brake Fluid Level: ______________ Window Washer Fluid Level: __________
Plug in Charger and Verify Function: ______________________________
Drive Vehicle: ____

NOTES:

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

City-el Service Report **Neighborhood Electric Vehicle Program**

VIN = ______________________

Date = ______________________

Service by = ______________________

Odometer Reading = ______________________

Parts Used

NOTES:

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

DAS Work Instructions

The following is the work instructions for installing the City-el Data Acquisition System as it is described by Pacific EV.

1.0.0 Termination Instructions

1.1.0 Under Dash Cable Reroute

Note: Use zip ties as necessary to anchor the cable.

1.1.1 Take off cover of fuse box on right side of the canopy.

1.1.2 Route the DB-25F cable through the box towards the front of the City-el.

1.1.3 Route the cable across the front of the vehicle just above the fan housing and underneath the large bulge under the dash. Make sure that the cable runs above the vent flapper cable.

1.1.4 Zip tie the cable through the small holes above the large hole in the aluminum gusset.

1.1.5 Route the cable back toward the dash panel along the aluminum box tube.

1.1.6 Locate the end of the DB-25F connector about 5 inches from the gusset.

1.1.7 Fold the excess cable back into the fuse box and replace the cover.

1.2.0 Battery Compartment Cable Routing

Note: Use zip ties as necessary to anchor the wires.

1.2.1 Undo coil of cable at the front right corner of the battery compartment.

1.2.2 Strip off the outer sheath of the cable about 6 inches from the left front corner location to the end of the cable.

1.2.3 Cut the white and the brown wires about 12 inches long. Route the wires to the front right corner where the existing thermistors are located.

1.2.4 Route the pink, gray, green and yellow wires from right to left across the front of the battery compartment. This is the edge of the battery compartment just behind the seat.

1.2.5 Route the pink and the gray wires from the left front corner down the left side and then right across the rear edge to a point just past the window washer reservoir.

1.2.6 Coil the green and the yellow wires and store them in the left front corner. Zip tie wires in place. Cut off extra zip tie length.

1.3.0 Battery Compartment Terminations

1.3.1 Locate one Sensor Scientific thermistor Part Number WM222C.

1.3.2 Cut thermistor leads about 1/2 inch shorter.

1.3.3 Cut two lengths of heat shrink tubing long enough to cover the thermistor leads and the solder joints. Place one piece of tubing over the white wire and another over the brown wire.

1.3.4 Solder one lead of the thermistor to the white wire and the other lead to the brown wire. Wrap the wire along the length of the thermistor lead so that the solder joint is not much larger than the wire itself.

1.3.5 Put the heat shrink tubing in place and place a third piece of tubing over both of the thermistor leads leaving the end of the thermistor exposed. This will hold the wires together near the thermistor.

1.3.6 Loosen the battery hold down bolt for the right battery and install the thermistor between the battery and the foam block. Poke a hole in the foam similar to the holes for the existing thermistors and install the thermistor through this hole.

1.3.7 Loosen the allen bolt above and to the left of the charger plug. This loosens the cover inside the battery compartment. It may be necessary to lossen some of the other allen bolts as well.

1.3.8 Remove the regular head screw located in the top of the charger plug. This allows the center of the plug to be removed from the housing.

1.3.9 Carefully pull out the charger plug while feeding the attached wires in from the battery compartment.

1.3.10 Route the pink and the gray wire from the battery compartment behind the panel and through the plug. A stiff piece of wire routed through the plug in the opposite direction will provide something to tie the wires to and draw them through.

1.3.11 Find two male pins for the Charger plug.

1.3.12 Solder one charger pin to the pink wire and repeat for the gray wire.

1.3.13 Plug the pin for the pink wire into the location for pin 8. (See drawing)

1.3.14 Plug the pin for the gray wire into the location for pin 7. (See drawing)

1.3.15 Replace the center of the plug and the regular head screw.

1.3.16 Re tighten the allen head bolts. Make sure all wires exit the relief area provided in the cover.

1.4.0 Hydria Watt-Hour-Meter Modification

1.4.1 Remove the back cover from the Hydria meter.

1.4.2 Pull off the plastic tubing holding the PC board in place, and lift the board slightly out of the enclosure.

1.4.3 Locate the vertical PC board in the upper left corner. The gray watt-hour counter wire pair is attached to this board. (See drawing)

1.4.4 Solder a 2.2 kohm resistor across the back side of the PC board connecting the two watt-hour counter wires together.

1.4.5 Reassemble the meter.

1.4.6 To avoid noise problems from the transformer velcro the Hydria meter to the top of the transformer box handle. A single strip of self adhesive velcro along the handle works.

1.5.0 Under Seat Terminations

Note: Route all wires along the main wire bundle that runs up the middle of the seat bottom.

1.5.1 Route the cable from the front right corner where it enters the under seat area along the existing cable bundle to the diagnosis plug. Do not zip tie this yet.

1.5.2 Cut the cable to a length that will allow the wires to be soldered into the diagnosis plug.

1.5.3 Strip off the outer sheath of the cable about 4 to 6 inches from the front right corner of the under seat area to the end of the cable.

1.5.3.0 Charge Shunt R2 Terminations

1.5.3.1 Route the brown, yellow, violet, red/blue, and brown/green wires over to the ground side of the shunt and cut to length. Leave enough for the connector. (See drawing)

1.5.3.2 Strip the end of each of the above wires, twist and solder together, and install in a crush-on loop lug that fits the bolt at the ground location.

1.5.3.3 Remove the top nut from the ground post. Install the above lug and replace the nut.

1.5.3.4 Route the red wire to the negative side of the shunt. (See drawing)

1.5.3.5 Cut the red wire to length leaving enough for the lug.

1.5.3.6 Strip the end of the red wire, tin the end, and install a crush-on loop lug that fits the phillips head screw.

1.5.3.7 Remove the phillips head screw. Install the above red wire lug and replace phillips head screw.

1.5.3.8 Route the blue wire to the positive side of the shunt. (See drawing)

1.5.3.9 Cut the blue wire to length leaving enough for the lug.

1.5.3.10 Strip the end of the blue wire, tin the end, and install a crush-on loop lug that fits the phillips head screw.

1.5.3.11 Remove the phillips head screw. Install the above blue wire lug and replace phillips head screw.

1.5.4.0 <u>Charger Connector J7 Termination</u>

1.5.4.1 Route the white/green wire to the charger connector. This is the 8 pin plug on the left rear of the under seat area. (See drawing)

1.5.4.2 Cut the white/green wire to length leaving enough wire to solder to the pin.

1.5.4.3 Remove pin number 8 from the plug. (See drawing)

1.5.4.4 Strip end of the white/green wire and solder it to the lower part of the pin. Wrap the wire around the lower part of the pin before soldering. Make sure that the wire will not prevent the pin from entering the plug. If necessary replace pin with Molex 0.082 female.

1.5.5.0 <u>Diagnosis Connector J2 Terminations</u>

1.5.5.1 Route the white, green, gray, pink, black, and gray/pink wires to the diagnosis connector.

1.5.5.2 Strip the end of all the above wires.

1.5.5.3 Remove pin 1 and solder the green wire to the bottom of the pin. This pin currently contains a red wire. Replace the pin. (See drawing)

1.5.5.4 Remove pin 2 and solder the white wire to the bottom of the pin. This pin currently contains a green wire. Replace the pin. (See drawing)

1.5.5.5 Remove pin 5 and solder the gray/pink wire to the bottom of the pin. This pin currently contains two pink wires. Replace the pin. (See drawing)

1.5.5.6 Remove pin 11 and solder the black wire to the bottom of the pin. This pin currently contains a blue and white wire. Replace the pin. (See drawing)

1.5.5.7 Remove pin 14 and solder the pink wire to the bottom of the pin. This pin currently contains two gray wires. Replace the pin. (See drawing)

1.5.5.8 Remove pin 13 and solder the gray wire to the bottom of the pin. This pin currently contains two white wires. Replace the pin. (See drawing)

Note: Wrap the wire around the lower part of the pin before soldering. Replace any damaged pins with Molex 0.082 dia. long male pins. Make sure to splay the pin clips slightly before reinstalling the pins. This will insure that the pins lock back in place.

1.5.5.9 Coil white/yellow and yellow/brown wires and zip tie to cable bundle.

1.5.5.10 Zip tie all wires. Cut off extra zip tie length.

2.0.0 DAS Construction and Installation

2.1.0 Resistor Modifications (See drawing)

2.1.1 Remove resistor bar from RP4.

2.1.2 Remove 22.1 kohm 1% resistor from R14 location.

2.1.3 Remove 22.1 kohm 1% resistor from R15 location.

2.1.4 Remove 22.1 kohm 1% resistor from R16 location.

2.1.5 Remove 22.1 kohm 1% resistor from R17 location.

2.1.6 Install 475 ohm 1% resistor in RP4A.

2.1.7 Install 475 kohm 1% resistor in RP4B.

2.1.8 Install 475 kohm 1% resistor in RP4C.

2.1.9 Install 10 kohm 1% resistor in RP4D.

2.1.10 Install 475 ohm 1% resistor in R14.

2.1.11 Install 475 kohm 1% resistor in R15.

2.1.12 Install 475 kohm 1% resistor in R16.

2.1.13 Install 10 kohm 1% resistor in R17.

2.1.14 Install 10 kohm 1% resistor in RN3D.

2.2.0 Jumper Settings (See drawing)

2.2.1 Remove all jumpers from J12.

2.2.2 Install jumper onto J12 pins 1 and 2.

2.2.3 Install jumper onto J12 pins 8 and 9. This is a diagonal jumper and will require some bending of the pins to get it to work.

2.2.4 Install J17 onto both pins.

2.2.5 Install J22 onto both pins.

2.3.0 Signal Conditioning Board Assembly (See drawing)

2.3.1 Locate one EVI signal conditioning board. See EVI drawing for details.

2.3.2 Install Signal Conditioning Board over J10 and J010.

2.4.0 DB-9M Connector Wiring (See drawing)

Important! Make sure that pin 1 on the DB-9M connector goes to pin 1 on the 10 pin connector.

2.4.1 Install ribbon cable on DB-9M connector.

2.4.2 Cut ribbon 9 wire cable 8 inches long.

2.4.3 Install other end of ribbon cable onto 10 pin connector with 10-10 spacing.

2.4.4 Install 10 pin connector with 10-10 spacing on J8

2.4.5 Install DB-9M connector in the end plate.

2.4.6 Put end plate on left side of the Little Giant board.

2.5.0 DB-25M Connector Wiring (See drawing)

Note: Wire the DB-25M pins to the Little Giant board and the Signal Conditioning board as listed below. For the Little Giant plugs, push down the lever and insert the stripped and tinned end of the wire then release the lever. For the Signal Conditioning board solder the wires to the proper location.

2.5.1 DB-25M pin 1 to Little Giant +9V IN plug.

2.5.2 DB-25M pin 14 to Little Giant GND plug.

2.5.3 DB-25M pin 2 to Little Giant CH0 LO plug.

2.5.4 DB-25M pin 15 to Little Giant CH0 HI plug.

2.5.5 DB-25M pin 3 to Little Giant CH1 LO plug.

2.5.6 DB-25M pin 16 to Little Giant CH1 HI plug.

2.5.7 DB-25M pin 4 to Little Giant CH2 LO plug.

2.5.8 DB-25M pin 17 to Little Giant CH2 HI plug.

2.5.9 DB-25M pin 5 to Little Giant CH3 LO plug.

2.5.10 DB-25M pin 18 to Little Giant CH3 HI plug.

2.5.11 DB-25M pin 6 to Little Giant CH4 LO plug.

2.5.12 DB-25M pin 19 to Little Giant CH4 HI plug.

2.5.13 DB-25M pin 7 to Signal Conditioning Board AC Watt-hours solder hole.

2.5.14 DB-25M pin 20 to Signal Conditioning Board AC Watt-hours GND hole.

2.5.15 DB-25M pin 8 to Signal Conditioning Board Charge Indic solder hole.

2.5.16 DB-25M pin 21 to Signal Conditioning Board Charge Indic GND hole.

2.5.17 DB-25M pin 9 to Signal Conditioning Board Speedo solder hole.

2.5.18 DB-25M pin 22 to Signal Conditioning Board Speedo GND hole.

2.5.19 DB-25M pin 10 to Signal Conditioning Board Ignition Indic solder hole.

2.5.20 DB-25M pin 23 to Signal Conditioning Board Ignition Indic GND hole.

2.5.21 DB-25M pin 11 EMPTY.

2.5.22 DB-25M pin 24 EMPTY.

2.5.23 DB-25M pin 12 EMPTY.

2.5.24 DB-25M pin 25 EMPTY.

2.5.25 DB-25M pin 13 EMPTY.

2.5.26 Install the DB-25 connector in the end plate.

2.5.27 Put the end plate on the right side of the Little Giant board.

2.6.0 EPROM Installation. (See drawing)

2.6.1 Program the EPROM with the MINDAS12.C program.

2.6.2 Install the EPROM as shown in the drawing.

2.7.0 Enclosure Assembly

2.7.1 Glue the Little Giant board to the enclosure base with a drop of super glue on each leg.

2.7.2 Locate one enclosure cover and slide it onto the base. Feed the DB-9M connector and end plate through the cover while sliding the cover onto the base. Make sure the DB-9M connector is on the left side of the Little Giant board.

2.7.3 Put bezels around each end plate.

2.7.4 Install two #4 phillips head screws in each end plate.

2.8.0 DAS Enclosure Installation

2.8.1 Use alcohol to clean a strip down the center of the bottom of DAS enclosure from one end plate to the other.

2.8.2 Adhere a 6 inch strip of 1 inch wide self adhesive black Velcro down the center of the bottom of the enclosure. Put the loop or "fuzzy" side of the Velcro on the enclosure. Leave the hook side of the Velcro attached to the "fuzzy" side.

2.8.3 Remove the wire tie from the top of the left side square aluminum tube.

2.8.4 Use alcohol to clean the top of the square aluminum tube on the left side of the canopy.

2.8.5 Remove the paper from the hook side of the Velcro leaving the Velcro attached to the box.

2.8.6 Center the box on the square aluminum tube and adhere the Velcro to the square aluminum tube. Make sure there is enough room to connect the DB-25 connector and the DB-9 connector.

2.8.7 Connect the City-el DB-25 connector to the DAS DB-25 connector.

3.0.0 Calibration and Testing

3.1.0 Calibration

3.1.1 Calibrate the DAS as described in the Calibration and Setup section of the DAS User's Manual.

3.1.2 Zero the DAS

3.2.0 Testing

Note: Refer to the DAS User's Manual to see how to perform the requested operations.

3.2.1 Test the DAS by monitoring the charging process at 1 second intervals. Verify that the Watt-hours, voltage, current, and temperature are working correctly. The Watt-hour counter should only click after the counter on the Hydria meter clicks.

3.2.2 Test the DAS by monitoring a quick test drive. Verify that the speed, voltage, current, and temperature work correctly.

3.2.3 Test the DAS by down loading the previous charge and trip. Verify that this is working correctly.

3.2.4 If everything works correctly zero the DAS. If things don't work, fix the problem and try again.

City-el Checkout List

VIN ________________

Date ________________

Milage ________________

KWHR ________________

Technician ________________

Cable Reroute ___

Rear
- Thermistor ___
- Transformer Connector ___
- KWHR Meter ___

Under Seat
- Shunt Connections ___
- Diagnosis Connector ___
- Charger Connector ___

Calibration ___

Test ___

Save File to Disk ___

Comments

____

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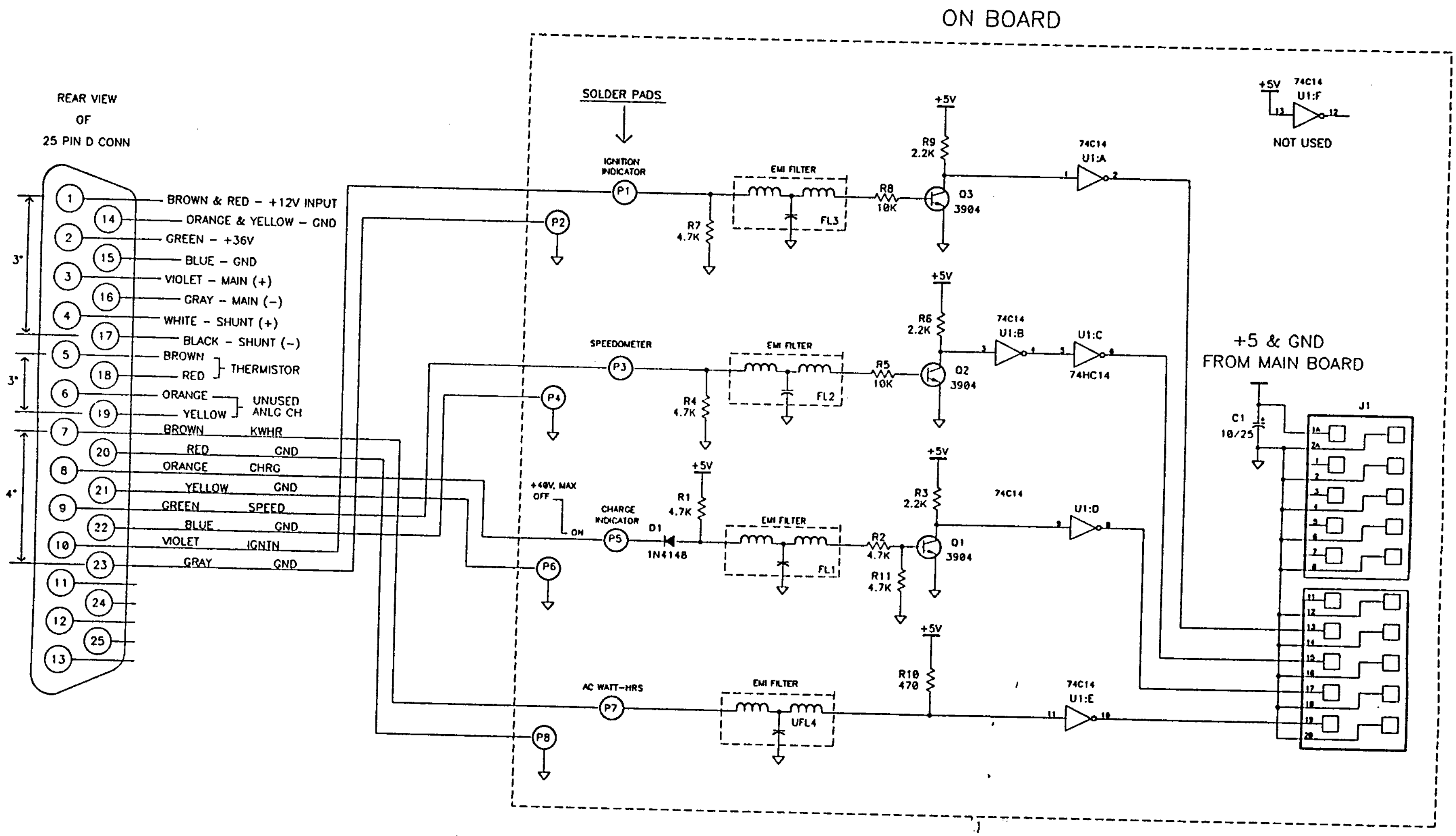

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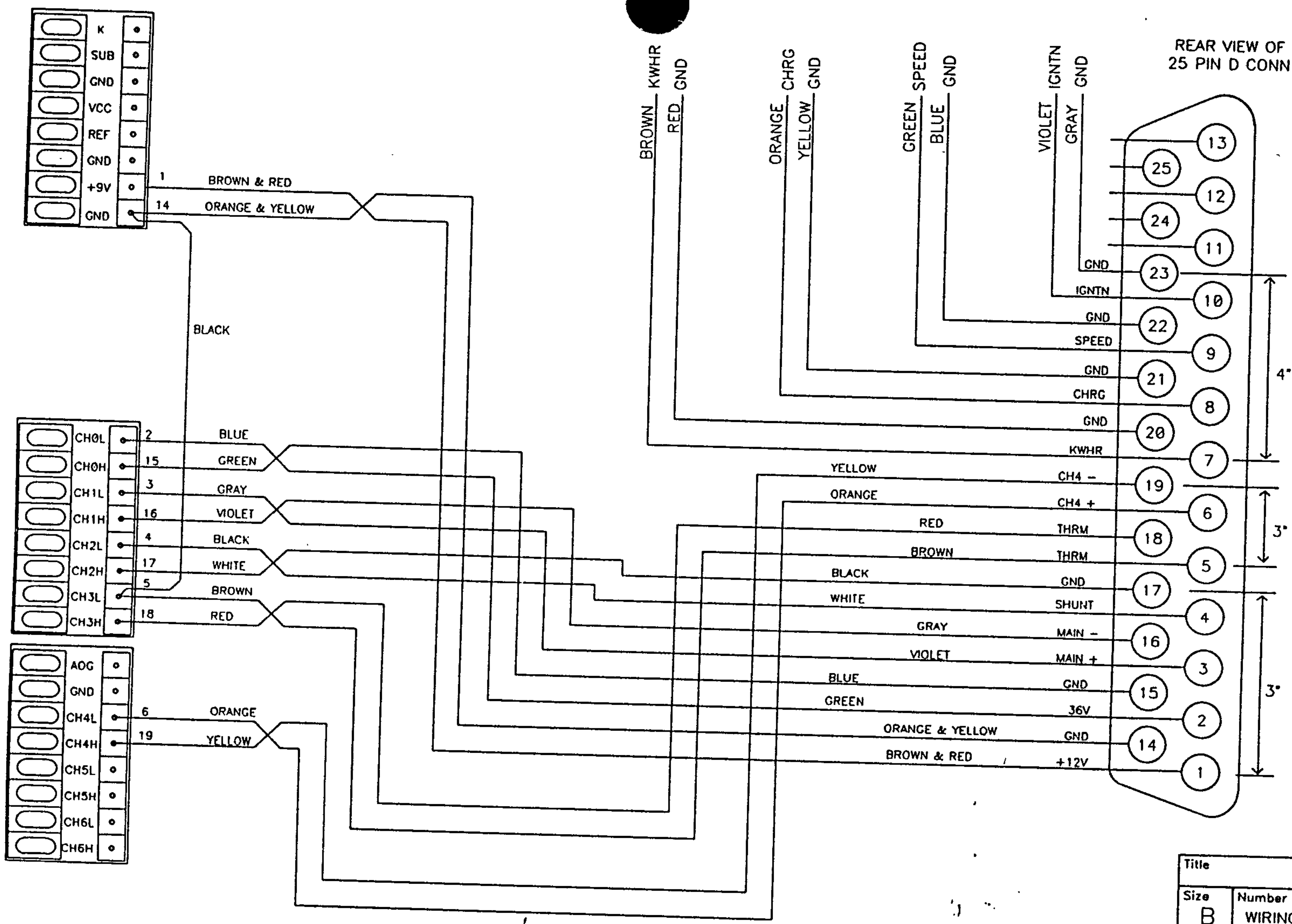
Size C	Number CITYEL PLUG-IN BOARD		Rev
Date 12 DEC 1994		Drawn by MR	
Filename PLUGBD.S01		Sheet 1 of 1	



Title	EVI, INC.	
Size B	Number WIRING – 25 PIN D CONN	Rev
Date 27 SEPT, 1994		Drawn by MR
Filename PLUGBD.S01		Sheet 1 of 1

Consequences and Wiring for Long Term Use of the Pepco Turbo-Z Charger.

1 February, 1995

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

REPORT: Consequences and Wiring for Long Term Use of the Pepco Turbo-Z Charger.
Prepared by: Lance Atkins, Pacific Electric Vehicles, 2-1-95

Purpose: This report describes what is involved to set up a City-el for a long term test of the Pepco Turbo-Z charger.

Scope: This document contains information on the consequences of hooking up the Pepco Turbo-Z charger for a long term test. Information on the effects to the user, the data collection, and the Data Acquisition System (DAS) is given below. A brief discussion on the possibility of using both the City-el charger and the Turbo-Z charger interchangeably is also provided. A wiring plan is presented followed by a brief summary of the operation of the Turbo-Z charger once wired to the City-el.

Conclusions: The Pepco Turbo-Z charger can be used in a long term test with the City-el. The most significant problem for the user is the lack of a properly operating capacity gage. More work should be done in this area to find an appropriate solution. Manual data collection will not be affected except that the user may need to write down the AC watt-hour reading from the 240VAC watt-hour meter after each charge. DAS charge data will not be available. Both chargers could be used interchangeably with some extra work but there are problems that would need to be resolved. Charging would be a simple plug in and unplug operation.

Consequences.

Once wired into the City-el, the Turbo-Z charger will have several effects on the user. For starters, there will be no charger light on the dashboard while the charger is operating. This is not a serious problem and is more cosmetic than anything else. Furthermore, the system will not turn the charger off when the key is turned on. This is probably not a significant problem. The charger may have a problem following the proper charge profile because of the extra current drawn while the key is on. However, as long as the operator turns the key off and leaves it off until the charger is finished, this is not a problem. Fortunately, this is also a fairly natural response for the operator. The safety interlock that prevents the vehicle from being driven while the charger is plugged in will still be operational. The capacity gage is probably the biggest problem for the user. With the Turbo-Z attached, it will not set to 100% charge or 12 dots. The best possible case will be 9 to 10 dots on the capacity gage. There are problems described in the next paragraph that may require that an entirely different way of measuring battery capacity be found.

The basic problem with using the existing capacity gage with the Turbo-Z charger is the high current output of the charger. The Turbo-Z charger currently has a charging current of 18 to 20 amps. This is higher than the 15 amp maximum that the charge shunt and capacity gage were designed for. At 15 amps the charge shunt has a voltage of 50mV which is read by the capacity gage. Maybe the capacity gage can handle the 66mV the Turbo-Z charger would create in which case there is no problem. Unfortunately, there is no documentation available to confirm this. If the charge shunt is changed to a value that provides the capacity gage with 50mV at 20 or 25 amps, the system will work. The down side to this is that, the capacity gage will read a current that is less than the actual current and will not increase the capacity gage as fast as it should. This will result in a fully charged battery pack while the capacity gage shows only 4 or 5 dots. If the 82% signal could be simulated just before the charger turned off, the capacity gage would be set to 10 dots and the problem for the user would be minimal. Simulating the 82% signal though would require some significant electrical and electronics work to the Turbo-Z charger. Using an entirely different DC watt-hour meter may be necessary, but more information and testing is needed to find the best solution to this problem.

With one exception, the manual data collection currently being done on the City-els will not be affected. The Hydria meter in the City-els can not be used to measure the AC watt-hours since the Turbo-Z charger is a 240V charger. This means that a different AC watt-hour meter must be used. The currently available 240V AC watt-hour meter only has one display and may require that the user write the number down after each charge.

The DAS can not be used to record charges with the Turbo-Z charger for several reasons. For starters, there is no AC watt-hour signal from the 240V AC watt-hour meter. Secondly, there is no charger on signal to put the DAS into the charge mode. Finally and most significantly, the operating frequency of the Turbo-Z charger causes accuracy problems with the current and voltage measurements. All of these problems could probably be fixed, but it would require the purchase of some more equipment and some significant electrical engineering time.

It may be possible to use both the City-el charger and the Pepco Turbo-Z charger alternately. This will add to the complexity of the installation but may be helpful for the user. For this to work, three wires must be cut when the Turbo-Z charger is used. The 17VAC line that attaches to J36 must be cut; the main charge cable at J39 must be cut; and the line at J7-1 must be cut. These three could be cut with normally closed relays activated by the micro switch on the Pepco charger socket. A check should be made to verify that this won't damage the City-el charger board should the City-el transformer be plugged in while the Pepco Turbo-Z is also plugged in. It should also be noted that this may cause the City-el charger to set the ETG light every time the Turbo-Z charger is used. The City-el charger seems to set the ETG light every time it is disconnected from the batteries. As a final note, changes to the charge shunt to accommodate the Turbo-Z charger may cause some problems with the capacity gage when the City-el charger is used.

Wiring

The wiring plan described below is for a simple installation of the Turbo-Z charger. The DAS is not available for charge information, and the Turbo-Z is the only charger used on the vehicle. The capacity gage problem is not addressed in this wiring plan other than changing the charge shunt to supply 50mV to the capacity gage at 25 amps. See the wiring diagram in the appendix.

The charge transformer box should be removed from the City-el. The black cable from the charge shunt to J39 on the charger board should also be removed. The plug J7 should be unplugged from the charger board. Finally, the charge shunt should be removed and replaced with a 50mV per 25 amp shunt.

The Pepco charger socket should be mounted to the City-el where the transformer box was. It may be possible to mount the socket through the interior wall of the City-el. Otherwise, it can be mounted to the interior wall with screws. A shielding box should be put on the socket for safety.

The positive cable from the socket should be run through the interior wall if necessary and attached to the negative side of fuse F9 located under the motor controller cover. Rout and zip tie the wire appropriately. The negative cable from the socket should be run with the positive cable and then back out the other side of the motor controller cover. It should then be run forward through the tube on the City-el and down past the emergency brake to the under seat area. At this point, it should be attached to the charge shunt opposite the common grounding point. Rout and zip tie the cable as necessary.

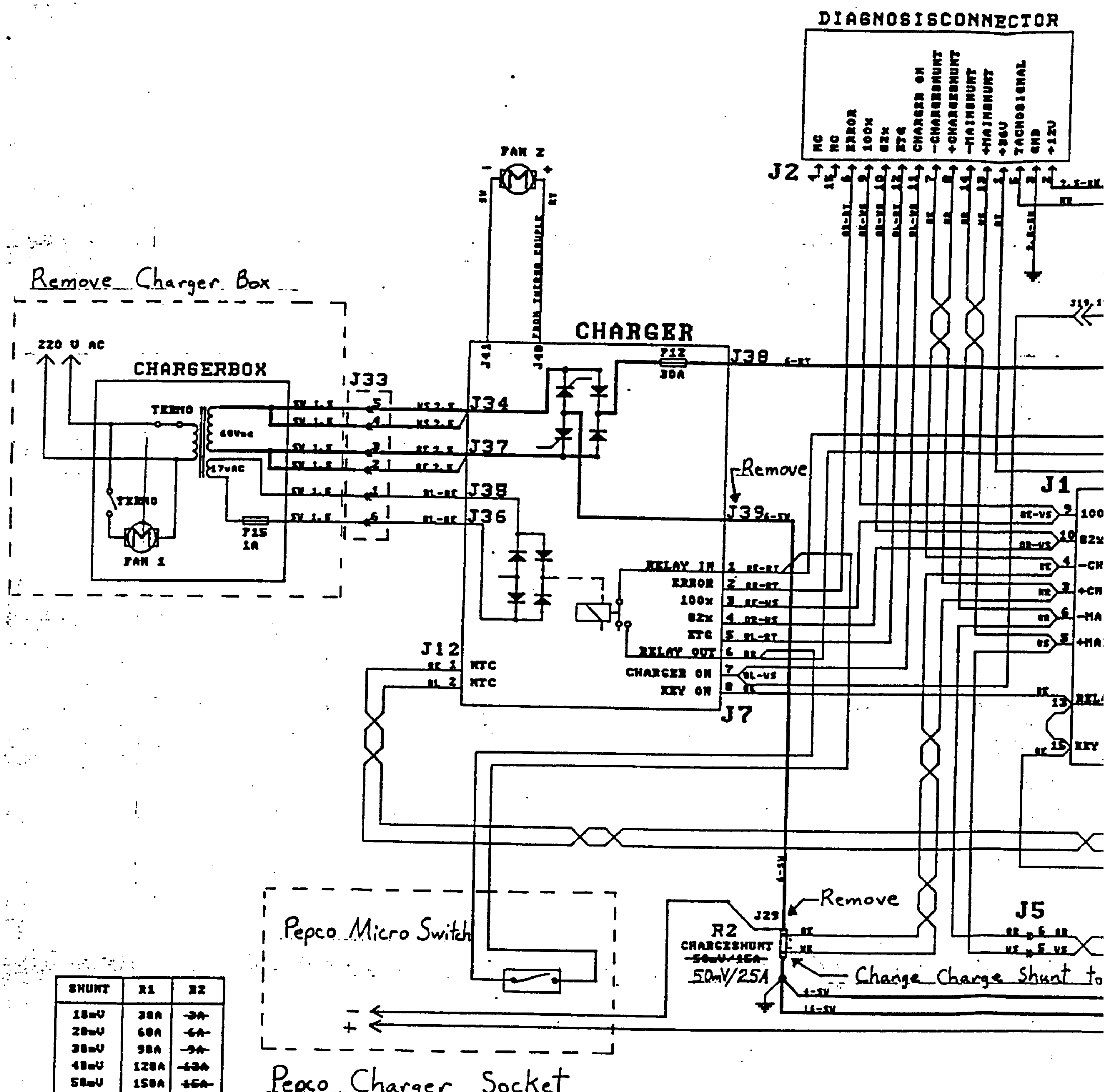
The leads from the Pepco charge socket micro switch should be routed along with the negative cable. Once they are under seat they should be wired to J7-1 and J7-6. The most elegant method for this would be to use a matching Amp plug for J7.

Operation.

Operation of the Turbo-Z charger with the City-el wired as described above is just like the Turbo-Z manual describes. The charger requires an indoor location with a 240VAC 30 amp service. The cord is plugged into the City-el to begin the charging process. One minute later the charger turns on and lights the red light on the front panel. When the charging is done the red light goes out and the green light comes on. Should the charger stay on over 5 hours the green light will be flashing. If the user wants to interrupt a charge, the station advance button must be pressed and the red light must go out before the City-el is disconnected. See the Pepco Turbo-Z Owner's Manual for complete instructions.

APPENDIX

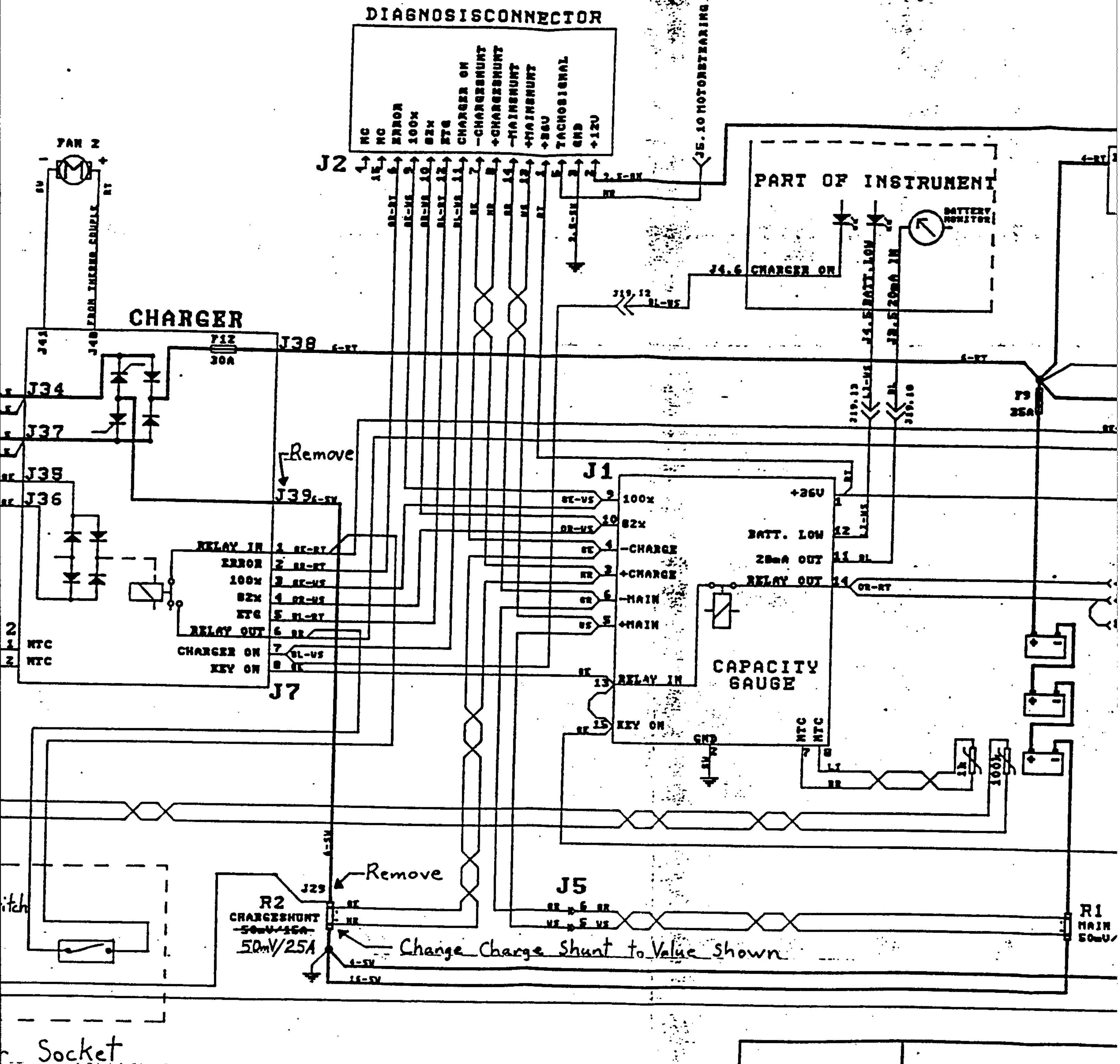
Order of Appendix Contents:	Pages and Designation:
Pepco Turbo-Z Charger and Capacity Gage Modifications	1 page Drawing



SHUNT	R1	R2
10mV	30A	~~3A~~
20mV	60A	~~6A~~
30mV	90A	~~9A~~
40mV	120A	~~12A~~
50mV	150A	~~15A~~

	ON	OFF
FAN 1	80 degC	65 degC
FAN 2	60 degC	45 degC

NTC THERMOCOUPLE		
TEMP.	CHARGER	CAPACITY
25 degC	100k ohm	1.00k ohm
15 degC	160k ohm	1.60k ohm
0 degC	340k ohm	3.40k ohm
-10 degC	585k ohm	5.85k ohm



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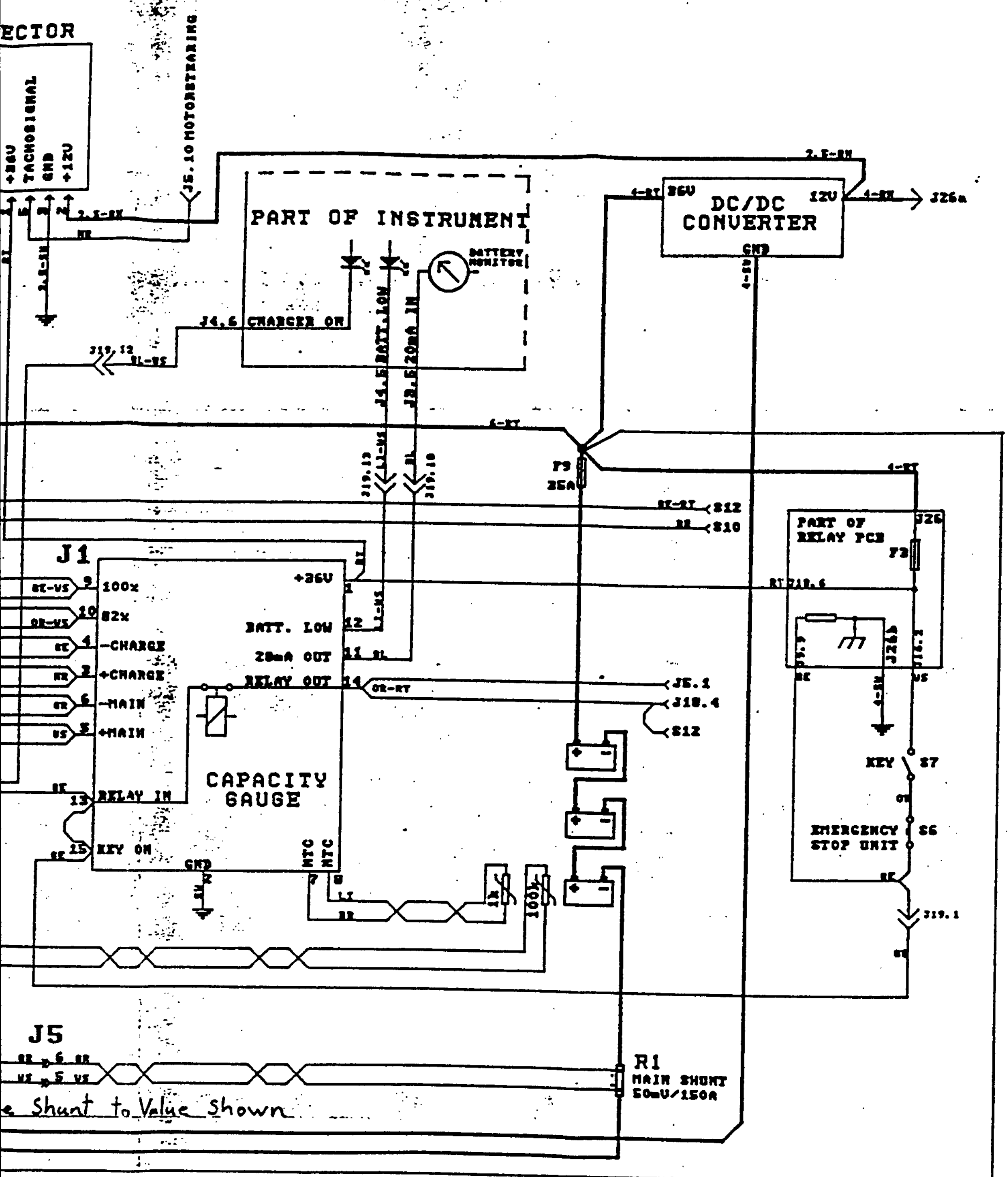
Prepared by: KJ, LA	Subject: Pepco Turb Charger and C Modificatio



CityCom	Workshop Manual	Section/Group: 7/2	No.: 3.1-0 Page 1 of 1
Date: 920907 2-3-95	Model:		Replaces:
Prepared by: KJ, LA	Subject: Pepco Turbo Z Charger and Capacity Gauge Modification		From VIN no.: 3006 To VIN no.:

3

Process Description: City-el Canopy Fabrication

19 April, 1995

Neighborhood Electric Vehicle Product Test and Development Project

Prepared By: William R. Warf
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

Process Description: City-el Canopy Fabrication

1.0 General:

The improved City-el Canopy is described on Pacific Electric Vehicles drawing D-00023. This canopy is designed to improve the safety of the City-el electric vehicle by replacement of the PMMA material used by CityCom on the original vehicles. The design also affords other improvements which are a reduction in the thermal expansion driven deformation of the top, improvement of the latching and sealing of the top part, and a reduction in component weight.

Because of the small quantity of parts needed, we chose to fabricate the new canopy by wet lay-up using polyester resin. While this is a labor intensive process, the tooling cost is low when compared with thermoplastic processed by thermoforming because of tooling and process development costs.

The new canopy is designed to accept the original convertible tops, and to mount on the existing aluminum sub frame. Front quarter vision is unchanged from the original design by inclusion of polycarbonate quarter windows. The original windshield and gasket as well as the canopy latch and canopy release lever are used with the new design.

2.0 Scope:

This document provides a summary of the process instructions for producing the Canopy Top up to the point where it is ready for installation on the vehicle. A bill of material, material descriptions, and process description and instructions are provided.

3.0 Materials:

Materials and quantities used in fabrication of the Canopies are provided in Table 1. Each of these materials is described in the following.

Resin

The new canopies are fabricated using Cargill 8450 isophthalic resin. Isophthalic resins are generally tougher, stronger, and have a higher heat deflection temperature than orthophthalic resin, and are generally about 25% more expensive. The Cargill 8450 is readily available and offers the following properties, as measured from clear cast test specimens. Laminate constructed according to this process plan may be considered to have a strength levels approximately 125% to 150% of these values. Higher values could be obtained by using more layers of continuous strand woven fabric as opposed to glass mat.

Material	Quantity,	weight	Thickness	Ideal resin
Gel Coat	2.0 Quart	4.00	0.0134	
Isophthalic Resin	5.5 quarts	13.06		
Mat 1.0 oz	120 ft^2	7.50	0.0250	10.71
Hexcell 3733 fabric 5.6 oz/yd f-16 finish	50 ft^2	1.94	0.0100	1.30
Adhesive	.33 Ga	3.63	0.0000	
		30.14	0.0484	12.01

Flexural Strength: 18,600 psi
Tensile Strength: 10,000 psi
Tensile Elongation: 2.3 %
Heat Deflection Temperature: 210 F

The Cargill 8450 has a relatively low viscosity and is easy to work with, while offering the minimal shrinkage and maximum part stability and strength, even at higher temperatures.

Reinforcements:
The fiber reinforcement in the canopy consists of two layers of 1 oz glass mat and one layer of plain weave fabric. The glass mat is fine strand style M127 from Verotex CertainTeed. Two layers of mat are applied over the gel coated surface of the molds, followed by one layer of plain weave fabric.

The fabric chosen is a 5.6 oz/ square yard fabric, Hexcel 3733 with an F-16 finish, conforming with MIL-Y-1140. This is a balanced plain weave fabric, meaning that there are equal fibers in both warp and fill directions. This fabric is a moderate weight, and is easy to work with. It is used to finish the lay-up, since it can be squeegeed to distribute excess resin and maintain a fairly high fiber content in the finished molding. Fabric lay-up directions are provided in the process description. In summary, the outer shell of the canopy is laid up with the plain weave fabric at +/- 45 degrees from the longitudinal part axis, while the inner part is laid up with the plain weave fabric parallel and perpendicular to the longitudinal part axis. This lay-up is intended to provide good torsional rigidity in the outer part, and good bending strength on the inner surface near the vehicle operator.

Gel Coat:
The gel coat choice for the Canopy at this writing is Neste 3000 series, which is a blend of ortho and isophthalic resins and binders. This is a flexible general purpose gel coat which we have successfully applied on the prototype parts produced to date.

Adhesive:
The inner and outer shells of the Canopy are bonded together with an adhesive prepared by mixing Cab-o-cil fumed silica with our 8450 Isophthalic resin. The resulting paste is harder than the base resin when cured and is difficult to sand. However, the paste adhesive retains the relatively high strength of the resin used, and has worked well on the prototype parts.

4.0 Safety, health physics

All personnel handling composite materials, or grinding or painting shall read the material safety data sheets for the materials used. The shop safety manual shall also be reviewed and understood. Respirators and other protective equipment are required. Read and understand all aspects of this process plan prior to commencing work.

5.0 Process Description:

This section describes the process of production of the fiberglass canopies. A process operational sequence is provided in Table 2. The following description utilizes the operation numbers from the operations sequence as an outline.

Cut out Mat and Fabric: (Operations 10 and 20)
Mat and fabric are cut out using patterns developed by laying poster board on the mold surfaces. There are twenty (20) patterns, as shown in Appendix 1 (three pages). This appendix shows the shape and proportion of the patterns, but is not to scale. The quantity and use of each piece is shown in Table 3. Following the cutting of the pieces, they are laid out on a work table for easy access during lay-up, and covered by the patterns. Note it is best to minimize the handling of the fabric prior to laying up, as the fabric will not hold it's shape well after being cut out.

Wax The Mold Surfaces: (Operation 30)
This operation is performed after production of *every 5th part.*
The entire working surface of the mold including flanges and base are washed and given two coats of McGuires Mirror Glaze No. 8 maximum mold release hard wax.

Wax Flanges and Mold base (Operation 40)
The Flanges and the Mold base are washed with clear water, allowed to dry, and are given two coats of Part-All No. 2 green paste wax.

Assemble The Mold: (Operation 50)
The six piece inner shell mold is assembled using 36 each 1/4-20 bolts.
See Figure 1.

Wax the Working Surface of the Molds. (Operation 60)
The entire working surface of the inner and outer shell molds, and the Targa mold are given two coats of Part-All No. 2 green paste wax. This paste wax acts as a prime coat for the PVA applied in operation 70.

Table 2

Operation	Canopy Fabrication Sequence:
10	Cut Out Mat Using Patterns
20	Cut Out Fabric Using Patterns
30	Hard Wax Mold Surface (Every 5th part)
40	Wax Flanges and Base of Mold
50	Assemble Mold (7 Pieces)
60	Part-All Paste Wax Mold Surf. 2 Coats
70	PVA mold surface, uniform coat
80	Mask Flanges before Gel Coat
90	Gel Coat Inner, Outer, and Targa Hoop
100	Cure 12Hours
110	Lay-up Targa Mold
120	Lay-up Outer Shell
130	Lay-up Inner Shell
140	Bond backing plates (5 Pieces)
150	Install Cable Housing and Bond
160	Cure 12 Hours
170	Grind Bonding surfaces
180	Bond Inner and Outer Part together
190	Cure 6 hours min.
200	Dissassemble Mold and de-mold part
210	Grind flash
220	Surface repair
230	Prep for paint if req'd
240	Paint
	Total Composite part fab:
250	Mechanical Preparation
	Total Cycle Time: 2.5 days minimum

TABLE 3, CANOPY LAY-UP SUMMARY

Pattern No.	Description	Inner Shell Mat Qty.	Inner Shell Fabric Qty.	Inner Shell Orientation	Outer Shell Mat Qty.	Outer Shell Fabric Qty.	Outer Shell Orientation	Targa Hoop Mat Qty.	Targa Hoop Fabric Qty.	Targa Hoop Orientation
1	Front	1	1	(0,90)	1	1	(45,45)			
2	Side support, Window	4	2	(0,90)	4	2	(0,90)			
3	Top, Window	2	1	(0,90)	2	1	(0,90)			
4	B-Pillar	4	2	(0,90)	4	2	(0,90)			
5	Targa Top				2	1	(45,45)	2	1	(0,90)
6	Targa Taper				4	2	(45,45)			
7	Back, Rear				2	1	(45,45)			
8	Rear, Side				4	2	(45,45)			
9	Cockpit, side	4	2	(0,90)	4	2	(45,45)			
10	Front, Side	4			4	2	(45,45)			
11	Side, Inner Only	4	2	(0,90)						
12	Back	4	2	(0,90)						
13	Front, bottom	4	2	(0,90)						
14	Handle	4	2	(0,90)						
15	Rear, corner, bottom	4	2	(0,90)						
16	Rear, Bottom	4	2	(0,90)						
17	Wheel Well	4	2	(0,90)						
18	Inside, Back	4	2	(0,90)						
19	Front Side, Inner,top		2	(0,90)						
20	Front Side, Inner		2	(0,90)						

Pattern Number Refers to figures in Appendix 1, see also operations sequence

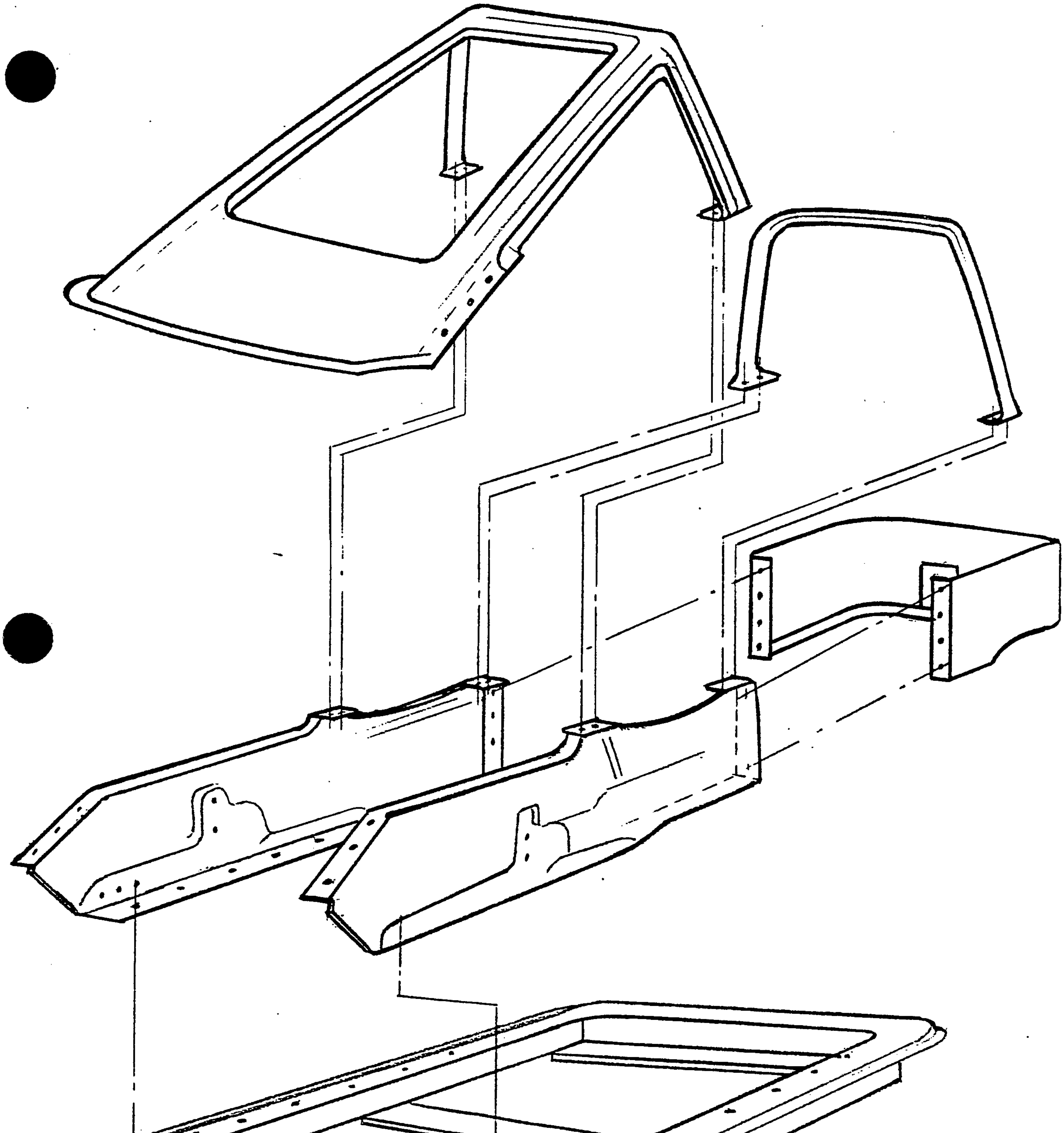


FIGURE 1

ASSEMBLY OF THE 6 PIECE INNER MOLD

Spray Release (Operation 70)
A uniform glossy coat 2 to 4 mils thick of Part-All film #10 poly vinyl alcohol (PVA) is applied to the working surface and exposed flanges to provide a water soluble release. Several thin coats are used to avoid runs. PVA must be dry before proceeding to operation 80.

Mask Flanges (Operation 80)
The exposed flange surfaces of the mold are masked with masking tape to prevent Gel Coat application.

Gel Coat Application: (Operation 90)
Apply 2 Quarts of catalyzed Gel Coat to obtain a uniform 10-14 mil coat of Gel Coat to the mold surfaces of the Inner Shell Mold, the Outer Shell Mold, and the Targa Mold. The Gel Coat is catalyzed with 15 cc of Hi-Point 90 Methyl Ethyl Keytone Peroxide (MEKP) per Quart of Gel Coat. (More is required below 60F, see manufacturer's data.)

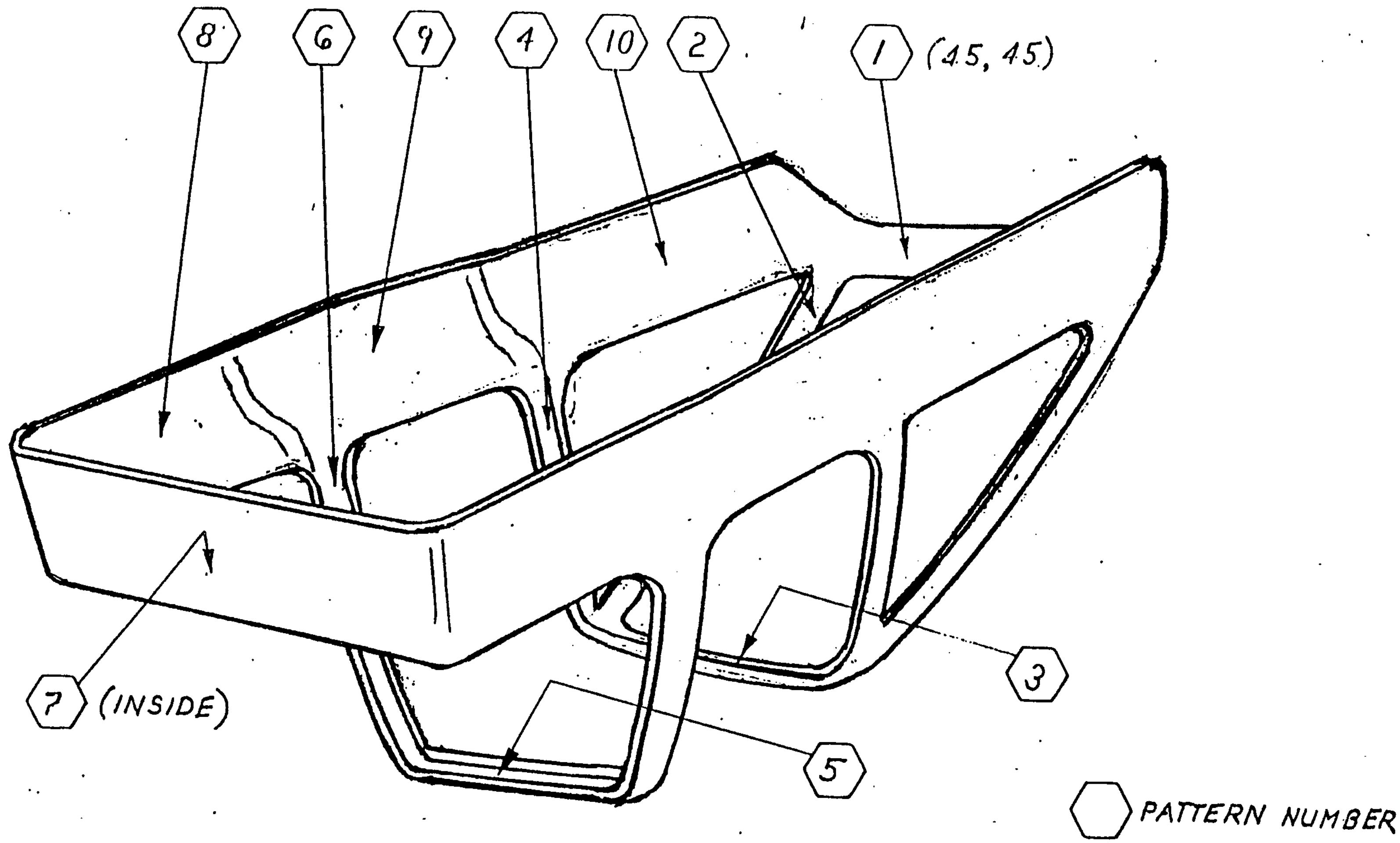
Allow Gel Coat to Cure (Operation 100)
Allow at least 12 hours of cure time prior to proceeding to operation 110.

Lay-up the Targa Mold. (Operation 110)
The lay up consists of two pieces of 1 oz mat cut according to pattern number 5. About 12 oz. catalyzed resin (10 cc/ quart or 3-4 cc MEKP at 68 F) is required. The mold is coated with resin and the mat applied and saturated and worked into the mold removing all air bubbles. A corner roller is used to work the mat into the corners. The second layer of 1 oz mat is then applied similarly. Finally a layer of 3733 fabric is applied with the fabric oriented (0,90) as shown in Appendix 1. A roller and a small squeegee are used to spread resin to remove the excess.

Lay-up the Outer Shell Mold. (Operation 120)
The Lay-up sequence and location of the fabric cut in operation 10 is shown on Figure 2. The lay-up starts by coating the mold surface with catalyzed resin at the front of the mold, and applying the first layer of mat. The windshield surround and top are completed, then the top of the targa hoop. The patterns are cut such that about 3/8 " of trim is left overlapping the edges of the mold. The first layer of mat is completed, overlapping each piece at least 2 ". Since it takes a little time for the mat to become saturated and pliable, coat the mat with resin and proceed to the next piece. A squeegee and a roller are used to remove air bubbles and work the mat into the mold surface after saturation. Once saturated, the second layer of mat is applied, again working from the front to the back of the mold, and from the top of the targa and windshield up to the sides in the inverted mold. Note that only one layer of mat is used at the front of the part, pattern number 1. Go back over the

FIGURE 2

OPERATION 120: LAYUP OUTER SHELL



NOTES: 1. ALL REINFORCEMENTS OVERLAPED 2" MIN. EACH LAYER.
2. SEE OPERATION SEQUENCE & APPENDIX 1.

laid up mat and work out the bubbles with brush, roller and squeegee. Finally the plain weave fabric is added in the same sequence, adding only enough catalyzed resin to wet out the mat and fabric, but not so much that excess is available to run, or be moved around much with the squeegee. Note when handling the fabric cut at (45,45) that it is easy to stretch out of shape, so handle it carefully. The total amount of resin used is about 2.5 Quarts. Once the resin starts to go off, and the lay-up becomes leathery and stiff, the lay up is trimmed using a razor blade knife. This trimming minimizes grinding and sanding dust later, however it must be done without disturbing the lay-up next to the Gel Coat surface, so timing is important, and the lay-up should be quite stiff, but not fully hardened.

Lay-up Inner Shell Mold, Operation 130.
Prior to performing this lay-up, the targa hoop molded in operation 110 is de-molded and clamped in place on the inner mold. The Lay-up sequence and location of the fabric cut in operation 10 is shown on Figure 3. The lay-up starts by coating the mold surface with catalyzed resin at the front of the mold, and applying the first layer of mat. Each piece of reinforcement is overlapped with the previous piece a minimum of 2 inches. Note that the mat and fabric pattern 11 is overlapped onto the targa hoop clamped to the mold, to form a continuous piece. The description of the process is very similar to the previous operation 120.

Note that when applying reinforcement cut according to patterns 9,10, 19, & 20 a 1/2" slit is needed to apply the mat over the studs in the mold. Saturate the reinforcement in place, and then slit.

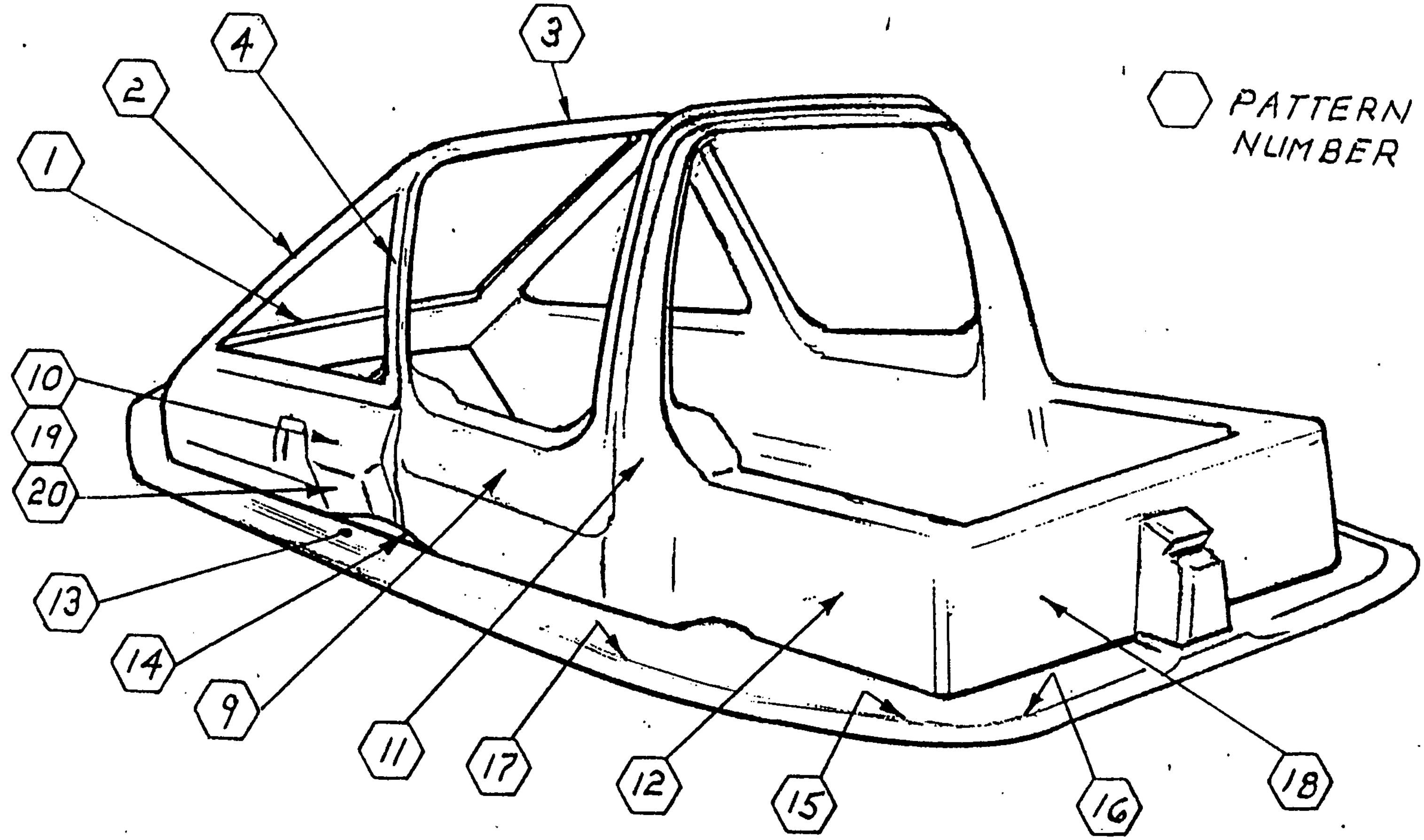
Note that when applying mat and fabric to the mold bottom, patterns 13,17,15, and 16, apply the reinforcement to the vertical bonding lip first and then fold it over as it becomes saturated to fit the flat portion of the bottom. This helps prevent bridging in this area.

After the lay-up becomes stiff and leathery trim to the edge of the mold using a razor knife, taking care not to disturb the lay-up from the mold surface.

Bond the backing plates (Operation 140)
Steel backing plates, part numbers A-31, A32, and A36 are bonded to the inner shell using an adhesive made by mixing Cab-o-cil with resin, and then catalyzing. Note that sufficient adhesive for this operation and operation 180 (21 ounces or almost 1.5 quarts) can be mixed, but not catalyzed. Catalyze only 4 Ounces of resin for this operation. The backing plates should have a mat blasted finish, and are stored in plastic wrap to prevent contamination. The plates are bonded to the front of the part on both sides and near the windshield base on both sides of the part

FIGURE 3

OPERATION 130 LAYUP INNER SHELL



NOTES: 1. ALL REINFORCEMENT OVERLAPS 2" MIN. EACH LAYER
2. SEE OPERATIONS SEQUENCE & APPENDIX 1.

using the studs set in the inner mold. The canopy latch lever plate is bonded on the right side of the part, using the stud set in the mold.

Install Cable Housing (Operation 150)
90 inches of 3/64" cable housing is installed on the inner shell and adhered with six places with 2" x 6" strips of fabric. The cable housing is inserted through the canopy latch lever in the hole provided, and through the raised dimple at the rear of the inner shell.

Cure (Operation 160)
Allow both lay-ups to cure at least 12 hours.

Grind Bonding Surface (Operation 170)
The bonding surface is abraded to break the glossy surface and provide a good bond. Be meticulous, and abrade all bonding lines, see Figure 4. Using the shop vac, remove all dust from inside surface of parts.

Bond Inner and Outer Shells together. (Operation 180)
Remove the masking tape applied in operation 80. Ready all clamps and fasteners before catalyzing adhesive since the adhesive will go off in 15 minutes when correctly catalyzed. If the fabricator is unfamiliar with this step, practice putting the halves together and clamping before catalyzing the adhesive.

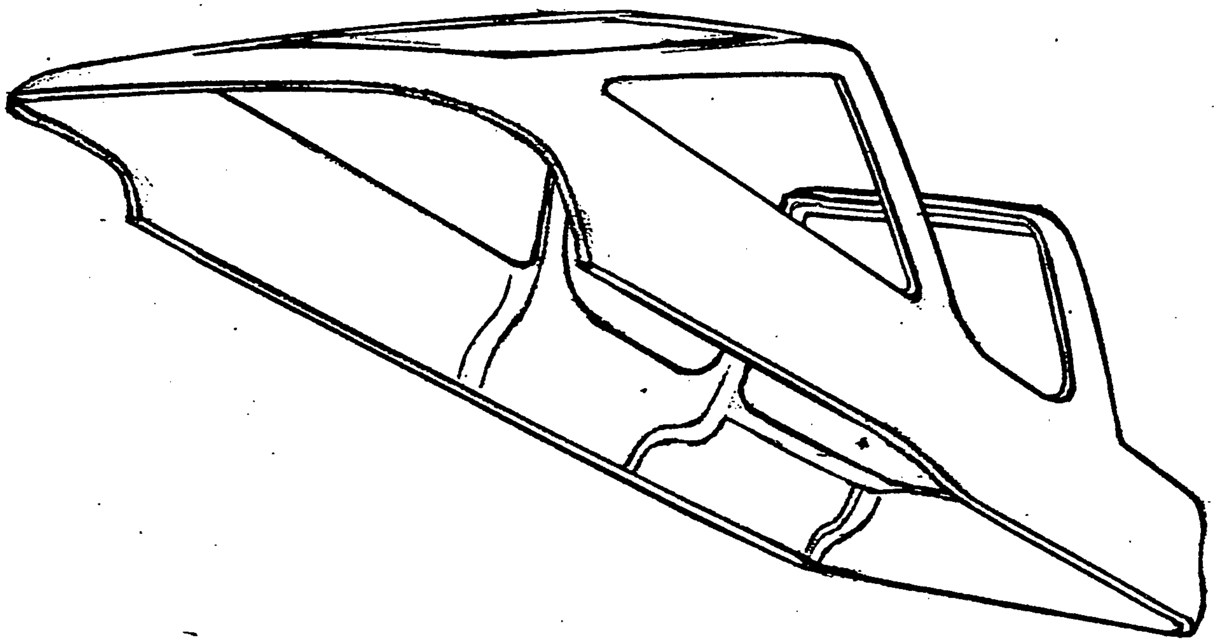
Apply catalyzed adhesive to the bonding surfaces on the inner shell as shown in Figure 4. Uniform application to all bonding surfaces is critical. After application, go back around the part and check uniform coverage! The Inner Shell, remaining on it's mold is inverted and inserted into the Outer Shell, which also remains in it's mold. The two molds are then bolted together around the base flange, the holes under the previously masked area. Clamps are applied around the windshield and targa hoop to hold the halves together tightly. Remove excess adhesive with a putty knife.

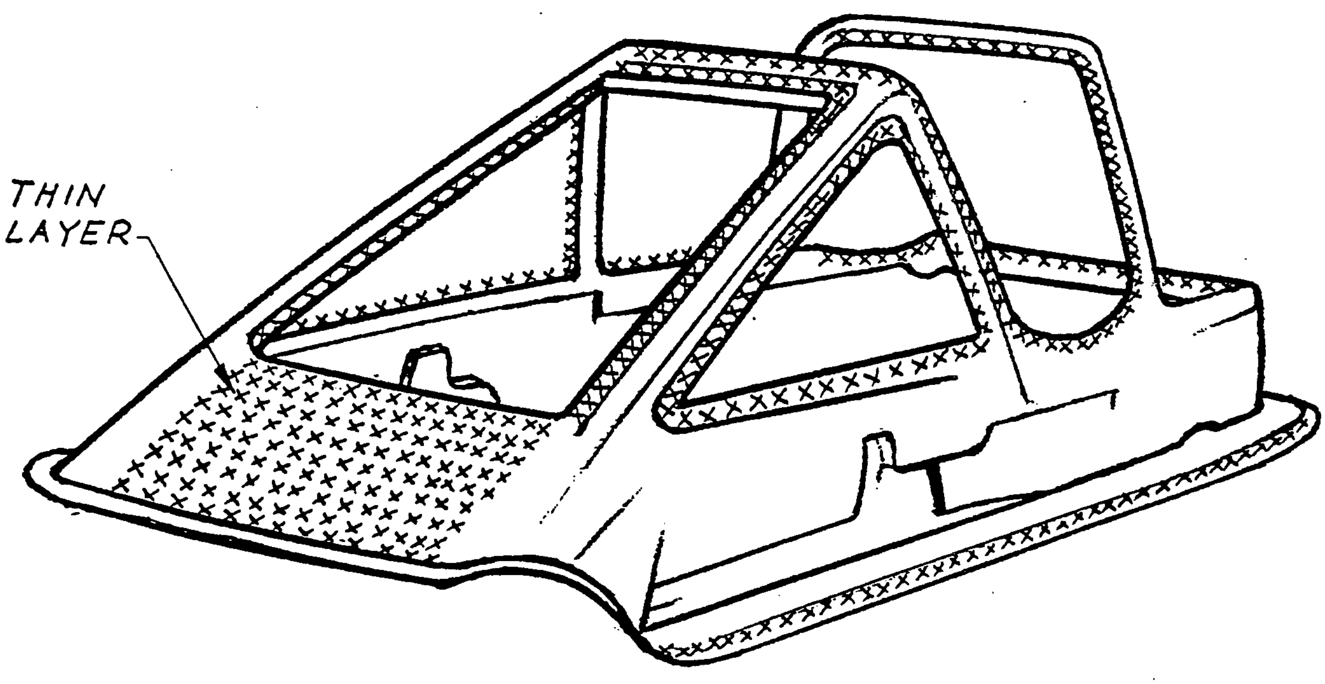
Adhesive Cure (Operation 190)
Allow the adhesive to cure at least 4 hours.

Disassemble Mold (Operation 200)
With the mold assembly sitting upside down on it's support, all bolts and clamps are removed and stored for subsequent operations. The bottom flange is removed followed by the inner sides of the mold. The inside back of the mold is removed, followed by the targa hoop and the windshield surround. Then the completed part is lifted from the outer shell mold.

FIGURE 4

BONDING PARTS TOGETHER





NOTE: MOLDS NOT SHOWN FOR CLARITY.

XXXXX = DENOTES ADHESIVE APPLICATION
SEE OPERATIONS SEQUENCE
OPERATION 170 & 180

Grind Flash (Operation 210)
The part is trimmed by careful grinding of the bonded edges. Care must be taken to preserve the gel coat surface. The grinding is followed by washing off with water, both the part and the mold to remove PVA. Wet sanding the flash areas on the completed part can now be accomplished with 400 grit paper.

Surface Repair (Operation 220)
Repair surface flaws as required using gel coat, bondo, or both and wet sand.

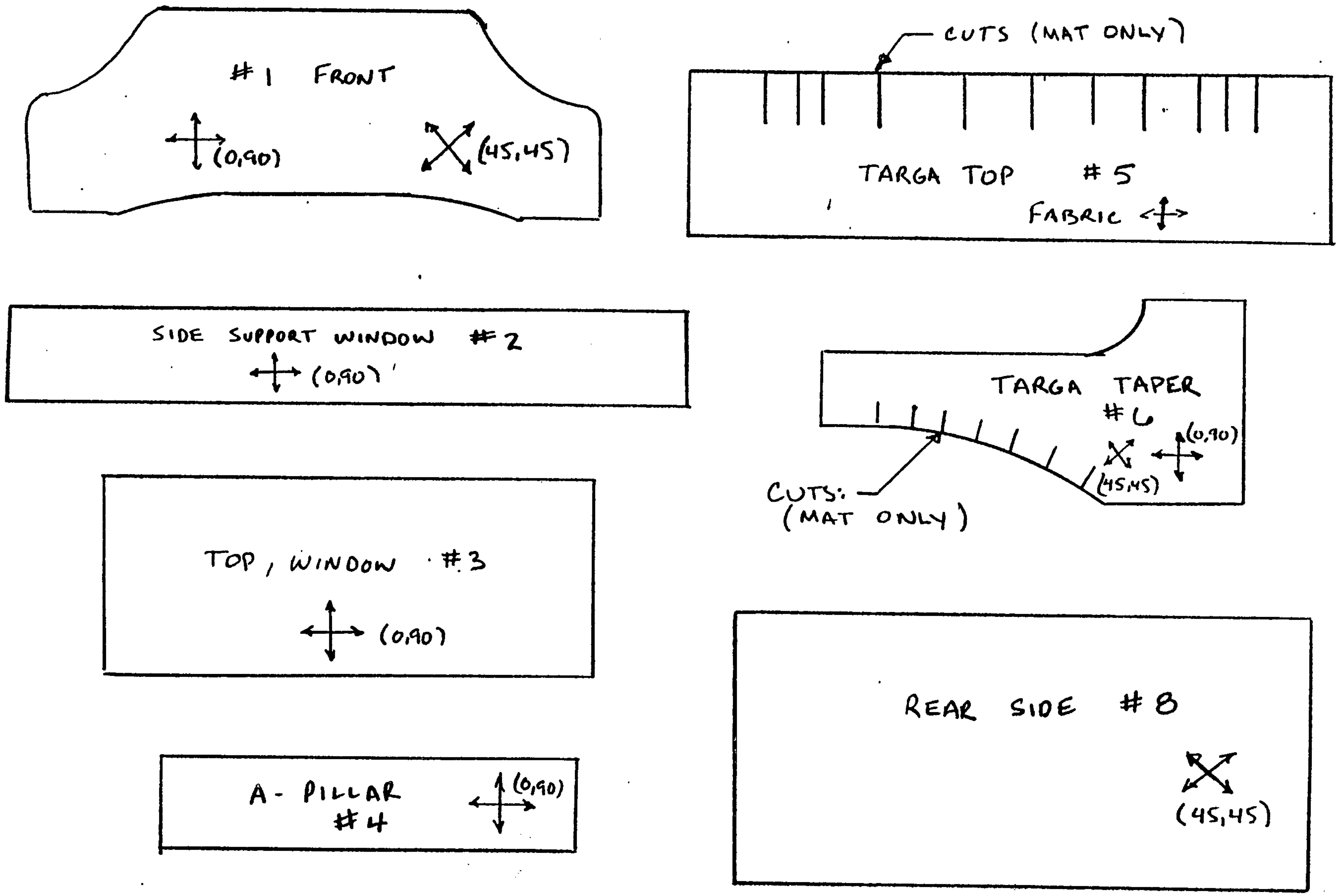
Prepare for Painting (Operation 230)
If color matched gel coat is not used, wet sand the entire surface to prepare for paint application.

Paint (Operation 240)
If required, paint completed canopy with Polyurethane Enamel to match the vehicle for which the canopy is intended.

Mechanical Preparation (Operation 250)
a) Drill holes for windshield wipers and washer.
b) Install quarter windows and windshield using original gasket. The quarter windows are retained by aluminum sash extrusion and (12) #6-20 x 1/4" long Phillips pan head screws.
c) Install latch hardware. Use latch plate drawing A-00033 as a template to drill holes, pop rivet latch plate in place, and use existing latch hardware and plastic cover from the top to be replaced.
d) Install hood release using 98" of 3/64" bicycle derailer cable and hardware and plastic cover from canopy top to be replaced.
e) drill holes for convertible top snaps, and install snaps with (17) #6-20 x 1/4" long Phillips pan head screws.
f) Install gasket from original canopy top or trim lock edging around the passenger opening.

The new canopy is ready for installation on a City-el.

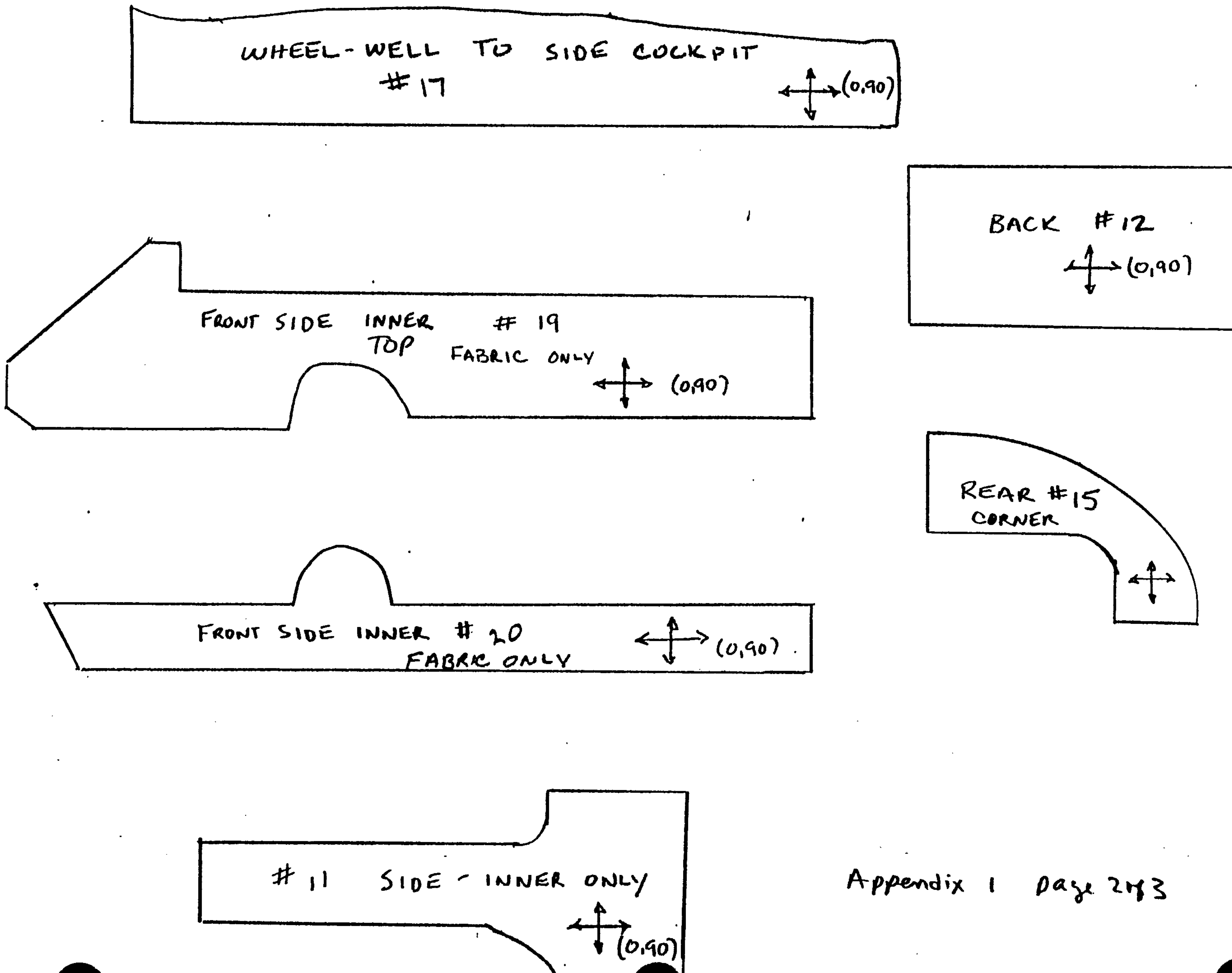
Append page 1 of 3



Appendix 1, page 1 of 3

BY .... DATE .... SUBJECT .... SHEET NO. .... OF ....
CHKD. BY .... DATE .... JOB NO. ....

Appendix . page 3 of 3



Appendix 1 page 2 of 3

BY .... DATE .... SUBJECT .... SHEET NO .... OF ....
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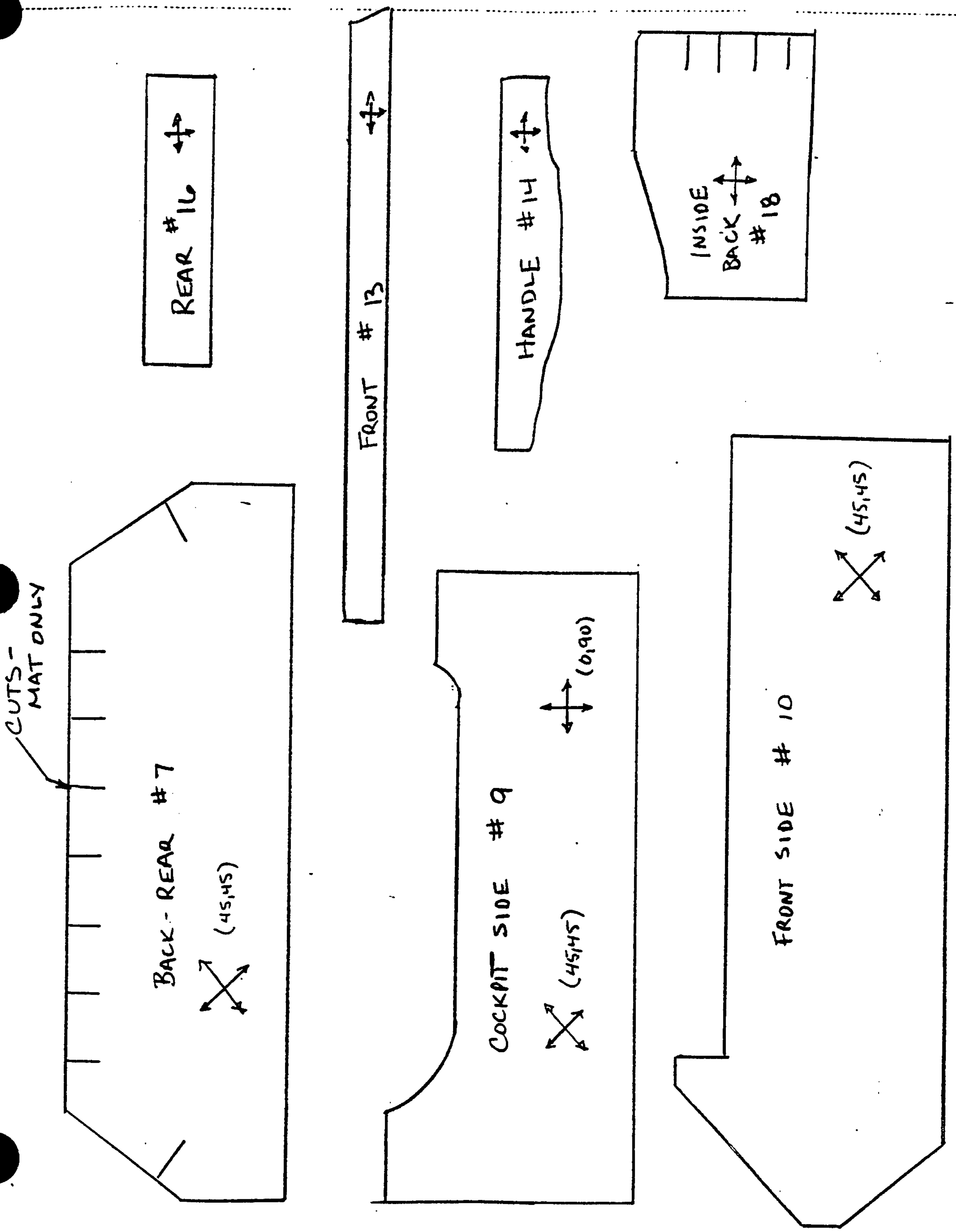


Appendix 1 page 3 of 3

CANOPY PARTS LIST		
Drawing Number	Part Name	Quantity
D-00030	Canopy Glazing	2
D-00023	Canopy Molding	1
A-00031	Nut Plate, Canopy, Aft	2
A-00035	Nut Plate, Canopy, Aft, LASER	2
	Bolt, Hex, M 8 x 1.25, 30 L	4
	Flat Washer, M8	4
A-00032	Nut Plate, Canopy, Fwd.	2
	Bolt, Hex Head, M6 x 1.0, 20 L	4
	Flat Washer, M6	9
A-00033	Nut Plate, Latch	1
A-00034	Nut Plate, Latch, LASER	1
	3/16 pop rivets, 3/8 Long	8
A-00036	Nut Plate, Latch Lever	1
	Bolt, Hex Head, M6 x 1.0 , 30 L	2
	Cable Housing, 90 " long	1
	Cable, 3/64 Derailer Cable, 90 " Long	1
	Nut, Nyloc, M6	1
	#6-20x 1/4 long phillips pan head scre	33
	Snaps from exisiting	1
	paint	1
	bondo	1
	Trim Lock	1
	Prep.	1
	Mechanical	1
	Aluminum Extrusion	1

Peregrin Body-Chassis Design,
Chassis Design Loads and Material Selection

1.0 Scope:
This document describes the body chassis and door loads, and material selection criteria used in the design of the Peregrin Neighborhood Electric Vehicle body - chassis. Also presented are the resulting material selection criteria, material specifications and a preliminary material list. An attempt has been made to design the composite structure with generalized material specifications, leaving the maximum number of choices for composite materials use, rather than to specify specific core and lamina material. The preliminary material list for the prototype lists rather specific material choices, while the selection criteria and materials specifications are expressed in terms of physical properties used in the analysis. It is hoped that this approach will lead to discovery of the lowest cost materials and processes capable of meeting the performance requirements.

2.0 General Design Approach: Body Chassis:
The over-riding design concern in design of the Peregrin body chassis has been to meet the destructive test requirements provided in Federal Motor Vehicle Safety Standards (FMVSS) 208, 214, and 216. These loads are much larger, in general, than suspension loads and over the road loading. A rough interior buck was produced, and a preliminary weight analysis done. The wheel base was changed from 2.3 meters to 2.2 meters in the interest of weight reduction, the main trade off being front to rear weight balance. Finally a full size body chassis model was constructed, and an overall layout drawing of the car was made. Analysis of the structure was performed in parallel with this effort, to assure the shell had sufficient room for a comfortable interior, as well as thick enough sections to sustain crash test loads and a minimum weight and frontal area.

Another concern has been to provide low unsprung weight and suspension travel as long as possible, to allow loading of the Peregrin with Cargo and Passengers which weigh up to 250 kg (550 lb), or 55% of the curb weight. The body had to accommodate this suspension movement without contact of tires with the interior of the shell. Front suspension travel is 7", and rear suspension travel is 8.5" full droop to full bump. Low unsprung weight and long travel mean that the Peregrin will carry it's load without unduly stiff springs. Attention to the suspension geometry has been undertaken, with the intent of providing good handling, again without undue harshness.

The design is a "cab forward" type passenger compartment, with all batteries located immediately behind the passenger compartment in a containment next to the drive. A substantial cargo bed is included above the battery containment, and

the drive. Suspension attachments are similar to those used on the 4 wheeled Persport- modified City-el.

In a side impact or door load test the wide doors are supported against primary bulkheads bonded into the shell. The Peregrin might be considered a modified hard shell vehicle, in that the design intent has been to provide a compliant section in the nose of the vehicle to absorb forward motion energy in a frontal barrier crash test. The passenger compartment is surrounded by very stiff shell sections on the sides, roof and floor, and is bounded fore and aft by the front and rear or battery box bulkhead structures. This means the Peregrin should be quite stiff in Roof Crush (FMVSS 216) and side impact (214) tests. The passenger and driver sit relatively far back from the dash and windshield to provide sufficient distance to decelerate driver and passenger, as would be the preferred design in a hard shell vehicle where higher deceleration are likely. This space in front of the driver provides a feeling of more interior volume.

The estimated curb weight of the Peregrin is 450 kg (992 lb), and a 1000 lb curb weight has been used in the design. Battery mass fraction is 40%.

The crush block in the nose has been modeled to provide a 40 g deceleration over a 12" (300 mm) crush distance for the car in a barrier crash test according to FMVSS 208. The balance of the structure including the battery containment has been designed for a 60 g crash load. Seat belt anchor inserts were designed for 80 g.

Additional discussion of loading and FMVSS compliance may be found in the Peregrin Safety Characteristics document.

3.0 Chassis and Door Load Summary:
The loads used in the design which relate to the FMVSS are shown in Table 1. In the design process, these loads were used to analyze the cored laminate shell or bulk head structures and the mechanical attachments.

Wheel loads and suspension loads are summarized in Tables 2 and 3. These are being used in the design of the suspension. Suspension mountings to the composite structure will follow the design developed for the 4 Wheeled City-el...Persport Vehicle, which provides good stiffness, distributes the load to the composites well, and facilitates simple suspension component fabrication and installation.

4.0 Analysis: The body chassis was analyzed and evaluated through the use of beam bending models. Each cored beam was evaluated on the basis of lamina strength and core shear strength. Core materials of different thicknesses and densities, shear moduli, bending moduli, and shear strength were evaluated. Along

TABLE 1. FMVSS Implied L ng for Peregrin design.

FMVSS, 49CFR 571-				Compliance	Loading Implied by standard
		F-102(11)c) submittal		Verification	
216	Roof Crush	2	Body Shell Design	Test	1500 lb to roof, 5" max deflect.
209	Seat Belt Assemblies	2	Body Shell Design	Test	1500, 2500, and 3000 lb to mounting
202	Head Restraints	1	Interior Design	Test	200 lb at headrest
207	Seating Systems	1	Interior Design	Test	20g and 3300 in-lb
206	Door Locks and Retention	2	Body Shell Design	Test	2500 lb any direction
214	Side Impact Protection	2	Body Shell Design	Test	3500 lb to door
208	Occupant Crash Protection	2	Body Shell Design	Test	50,000 lb over 12" crush
210	Seat Belt Assy. Anchorage	2	Body Shell Design	Test	5000 lb to belt
212	Windshield Mounting	15	Glazing Design	Test	60 g design
101	Controls and Displays	1	Interior Design	Test	
107	Reflecting Surfaces	1	Interior Design	Test	
111	Rear View Mirrors	1	Interior Design	Test	
124	Accelerator Controls	1	Interior Design	Test	
201	Occupant Protection In interior Impact	1	Interior Design	Analysis + test	
213	Child Restraints	1	Interior Design	Test	
108	Lamps	2	Body Shell Design	Supplier Mark + Test	
113	Hood latches	2	Body Shell Design	Test	
114	Theft Prevention	2	Body Shell Design	Test	
204	Steering Control, rearward displacement	2	Body Shell Design	Test	
219	Windshield Zone Intrusion	2	Body Shell Design	Test	
301	Fuel System Integrity	2	Body Shell Design	Test	
102	Shift sequence, interlock, braking effect	4	Drive	Test	
109	Tires	6	Suspension Design	Supplier Mark	
110	Tires and wheels	6	Suspension Design	Supplier Mark	
211	Wheel Nuts, wheel discs, hub caps	6	Suspension Design	Supplier Mark	
203	Impact Protection: Steering	9	Steering system design	Test	
105	Hydraulic Brake System	11	Brake system Design	Test	
106	Brake Hoses	11	Brake system Design	Supplier Mark	
116	Brake Fluid	11	Brake system Design	Supplier Mark	
205	Glazing Materials	15	Glazing Design	Test	
103	Windshield defrost	17	Glazing,defrost, HVAC	Test	
104	Windshield wipers	17	Glazing,defrost, HVAC	Test	
115	VIN Number	n/a	Pre-production	Design	
302	Flamability of Interior Materials	n/a	Pre-production phase	Supplier Mark	

Table 2:		
Peregrin Rear Suspension Loads:		**Note:**
Upper Trailing Link	300 lb compression to 1225 lb compression	
Lower Trailing Link	300 lb Compression to 825 lb Tension	
Lower Horizontal Link:	746 lb compression to 625 lb Tension	
Upper Horizontal Link	256 lb compression to 625 lb Tension	
Spring-Shock, max load	1200 lb compression	
Wheel Load: static,	328 lbs	
3 g design load	1878 lbs	
Peregrin Front Suspension Loads		
Spring Shock	862 lbs	
Upper Arm:	150 lbs Tension to 300 lbs compression	2
Lower Arm	600 lb compression-600 lb tension	2
Wheel Load, static	218 lb	
Wheel load max bump	530 lb	
3 g design load	1764 lb	
Notes:		
1. See Layout for orientation of suspension components		
2. Estimated from Persport Calcs, needs check.		

Table 3, Peregrin: Summary of Wheel Loads							
Case	Total weight	Both Wheels, Front		Both Wheels, Rear		CG Station	CG Waterline
Curb Weight	1007	351	35%	656	65%	56.42"	9.79"
One Passenger	1197	436	36%	761	64%	55.08"	10.3"
Two Passengers	1327	494	37%	833	63%	54.39"	10.56"
Two+Cargo	1548	523	34%	1025	66%	57.33"	13.91"
1.0 g Brake	1327	732	55%	595	45%	54.4"	10.1"
0.25 g Acceleration	1327	433	33%	894	67%	54.4"	10.1"
	total Weight	Front	Front	Rear	Rear		
Wheel Loads, turning and:		Inner	Outer	Inner	Outer		
1.0 g turn	1327	103	391	207	626		
1.0 g turn and brake	1327	144	588	81	514		
		Weights in lbs.					
Note: for design above loads are used in the vertical direction,							
and in brake and turn cases the horizontal and vertical directions.							

with the effect of different laminate thicknesses. The core thickness and lamina were ultimately chosen to limit the core properties to those attainable with PVC foam core, although honeycomb or other core materials of equal properties can be substituted. Stresses and deflections were calculated. The most important stresses are shown in Table 4.

5.0 Material Selection Criteria:

In addition to choosing material to meet the strength and deflection criteria described above, material was selected based on the processes available for fabrication and the desire for a low mass, rigid structure. For a 1000 lb vehicle capable of meeting the FMVSS a fiber reinforced, cored composite structure appears to be in order. In selecting composites, the matrix or resin, the reinforcement fibers, and the core material (if used) must be selected.

5.1 Matrix Material; Selection Criteria

Matrix material choices are limited to thermoset plastic for the Peregrin prototype and early production of the Peregrin, because of tooling cost. Thermoset plastic can be used to make good parts in smaller volume, using thermoset plastic tooling. *Lamina stresses are kept as low as possible, to allow later substitution of thermoplastic matrix, where appropriate and cost effective, as production grows.* Epoxy Resin is chosen over polyester mostly because of it's superior elongation and toughness.

Epoxy can be combined with long fibers by hand lay up to yield excellent components in small quantities, using composite tools. Epoxy can be reformulated for incrementally higher volume (compression molding or RTM) or higher quality (vacuum bag, pre-preg systems). Table 5 provides clear cast (no reinforcement) properties of several epoxy grades, and the good quality polyester being used for canopy top fabrication. Note the benefit of a post cure in both ultimate elongation and strength with the 1362/3134 system.

Epoxy is relatively safe to use, releases no volatile organic compounds during cure, bonds with many core materials, and is tougher than polyester resins.
For the prototype, we intend to use a 1371/3171 Jeffco Epoxy system. This resin will allow us to have sufficient pot life to vacuum bag the core materials to the shell to achieve appropriate shear strength with a one piece mold. The 1371/3171 offers good properties and an adequate Heat Deflection Temperature (HDT) with a room temperature cure. This system also exhibits low exudation of material following the cure, which allows easier finishing and more flexible material use.

Table 4, Peregrin Chassis ɹd Summary Material Criteria

Location	Load Summary	Laminate Thickness (inches)	Core Thickness (inches)	Lamina Allowable (psi)	Core Shear (psi)	Note
Roof and Floor	1500 lb point load	0.050	0.67	21000	80	
Edge of Roof	1500 lb point load	0.080	1.25	98000	40	Long, narrow beam, idealized conservatively
Side Shell	3500 lb point load	0.050	1.00	21,600	100	
Nose and Wings	350 lb point load	0.050	0.13	30000	145	
Door Beam	3500 lb point load	0.060	3.00	32380	145	Built up section in prototype
Front Bulkhead	50,000 lb distributed load	0.125	various	26,000	145	Reinforced cut & fold, See layout
Battery Bulkhead	26,136 lb distributed load	0.125	10 mm	17689	105	Reinforced cut & fold, See layout
Seat Belt anchors	5000 lb min.	0.100		12000 shear		Insert, threaded
Door hinges& latches	2500 lb any direction	0.125	various	26,000	145	Attaches to front bulkhd/Battery Bhead

Resin Systems Comparison

TABLE 5

Property		Epoxies			Polyester
	1308/3102	1371/3171	1301/3141	1362/3134	8450 Iso
Pot Life (minutes)	15-20	90-100	15-20	100+	17-19
Elongation	3%	4%	5%	6.20%	2.30%
Tensile Strength (psi)	7,500	8,700	9,500	10,000	10,000
Flexural Strength (psi)	14,000	14,500	17,870	23,000	18,600
Flexural Modulus (psi)	350,000	350,000	350,000	360,000	430-530 ksi
Cure	77F	77F	77F	300F	77F
HDT (Note 1)	167F	143 F	175F	300F	210 F
Viscosity (cps)	600	750-900	2500	1000	400-500
Process	Hand layup	Large-bag	press	RTM/bag	Hand Layup

Notes:

1. HDT relates to the elevated temperature deflection under a 264 psi flexural stress test according to ASTM D-648-264, clear resin sample.

5.2 Reinforcements; Selection Criteria:

Glass fiber reinforcements (E-Glass) are used because they are compatible with our processing capability, readily available, and the least expensive fiber available with adequate properties. Higher grades of fiber are available at higher cost. Laminating will be done such that the balanced warp and fill fabrics in the laminate are oriented at 45 degrees to adjacent layers. The thinnest laminate in the Peregrin body shell is about .050 thick, and is comprised of one layer of matt, and five layers of fabric. A sample lay-up schedule worksheet for this laminate is given in Table 6. One square foot samples of the lay-up are produced using the same fabrics, orientation, and core to confirm thicknesses and weight and check the process, prior to making the lay-up of the given section of the shell.

E Glass plus epoxy resin can give laminates with flexural strengths in excess of 90,000 psi. The flexural modulus has been estimated as 5.6E6 psi, and the maximum stress in the structure is expected to be on the order of 32ksi (see Table 4). It should be noted that a 30 ksi stress is equivalent to an elongation of about 1/2 %, which is expected to be about 25% of the ultimate elongation of the laminate.

Openings in the Chassis Structure of the Peregrin Prototype utilize a layer of Carbon fiber covered by one layer of Aramid fiber to prevent shard creation near the maximum fiber of the inner and outer laminate. Analysis of the edges of the wind shield, door, and rear cover openings suggests that this area will have lower core shear stresses, lower deflection, and higher lamina stress with the addition of a layer of higher modulus fabric. High stiffness of chassis in the thinner section of the windshield surround and along the top of the doors provides benefits in regard to windshield retention, overall chassis stiffness, and minimizing deflection in the FMVSS 216 roof crush test. Note the laminate stress estimate based on a conservative model of this area is about 98 ksi in the roof crush test.

All composites texts reviewed to date state that analytical models must be checked by physical testing. We have therefore chosen modest allowable stresses using conservative analytical models, and plan to perform physical tests on samples constructed during prototype construction and using the prototype tooling.

5.3 Cores, Selection Criteria:

Core material have been selected based on their shear strength, commercial availability, cost, and ease of fabrication. Shear strength needs were provided in Table 4. Extensive use of cut and fold fabrication using Ciba Aerolam board will be done to fabricate the bulkheads and sill beams in the prototype. These cut and fold beams are reinforced to the required strength by adding laminate to the surfaces of the beams. This method is quick, and can be performed without molds.

Lay-up worksheet:												
Layer	Material	Fabric	oz/yd	area	wt. fabric	wt. resin	total wt.	orientation	vol. resin	vol. resin	Predicted	Effective
		thickness			lbs	lbs	lbs		in^3	oz	Thickness	thickness
1	Matt, 1oz	0.009	9.000	1 ft^2	0.063	0.094	0.156	ran	2.254	1.249	0.019	0.007615
2	1522	0.006	3.700	1 ft^2	0.026	0.031	0.057	0,90	0.755	0.418	0.007	0.007
3	DB090	0.012	9.300	1 ft^2	0.065	0.079	0.144	45/45	1.897	1.051	0.017	0.012362
4	1522	0.006	3.700	1 ft^2	0.026	0.031	0.057	0,90	0.755	0.418	0.007	0.007
5	DB090	0.012	9.300	1 ft^2	0.065	0.079	0.144	45/45	1.897	1.051	0.017	0.012362
6	1522	0.006	3.700	1 ft^2	0.026	0.031	0.057	0,90	0.755	0.418	0.007	0.007
Totals		0.050			0.269	0.346	0.615		8.313	4.607	0.075	0.053
					Total volume	10.782	in^3					
					Wght/in^3	0.057						
					sg	1.579						
Work sheet versus physical sample:												
Layer	Material	Fabric	oz/yd	area	wt. fabric	wt. resin	total wt.		vol. resin	vol. resin	Predicted	Effective
		thickness			lbs	lbs	lbs		in^3	oz	Thickness	thickness
Sample predicted												
with no matt		0.041	29.700	1 ft^2	0.206	0.252	0.458		6.060	3.358	0.056	0.046
Physical	Sample				0.156	0.188	0.344			about 4.5 oz	0.057	
											.054-.061	
				Actual SG	1.160							
							Actual wt. /ft^2					
							0.344					
Predicted foam core laminate including				1.052	lb/ft^2							
matt and 1/8" 5 lb divinycell												

Table 6. Sample Layup and Lay-up work sheet

Aramid honeycomb, available from Erskine Johns as surplus, and PVC foam will be used as core materials in the shell of the prototype. Table 7 shows some core material choices in comparison.

6.0 Material Specifications:
The material specifications for the Peregrin can be generalized for the Laminate and the Core. The adequacy of a composite structure's load-deflection and ultimate strength should be confirmed by physical testing, so these are preliminary specifications.

6.1 Laminate, Specification:
The laminate used for construction of all parts except around the edges of the roof, windshield, and upper door openings on the Peregrin chassis must be capable of stresses up to 32,000 psi without exceeding the elastic limit. A modulus of 5.6E6 psi nominal has been assumed, a modulus of 4E6 psi would be acceptable. The laminate shall exhibit an ultimate strain of 2% minimum. This specification is based on the load models, core properties, and thicknesses assumed in stress analysis as shown in Table 4.

The edges of the roof, windshield, and upper door openings must be capable of 100,000 psi flexural strength without exceeding the elastic limit. This may be within the reach of a glass fiber reinforcement and epoxy resin, however one layer of Aramid over Carbon will be evaluated in the prototype.

6.2 Material Specification: Cores:
Cores shall exhibit the minimum shear strength specified in Table 4. If the modulus of the core varies from the properties of the Core shown in the material list, the analysis must be performed again to check all stresses and deflections to avoid a shear failure.

Incorporation of cores into the structure shall be performed with a vacuum bag or other uniform clamping device to assure a complete shear bond.

6.3 Preliminary Material List.
A preliminary material list for the prototype body-chassis shell is provided in Table 8. The table shows the estimated weight and surface area of each part of the body chassis unit. Materials to be used in the prototype are described, along with the lamina a core thickness. Some notes are added to discuss the materials expected in low volume production.

Table 7

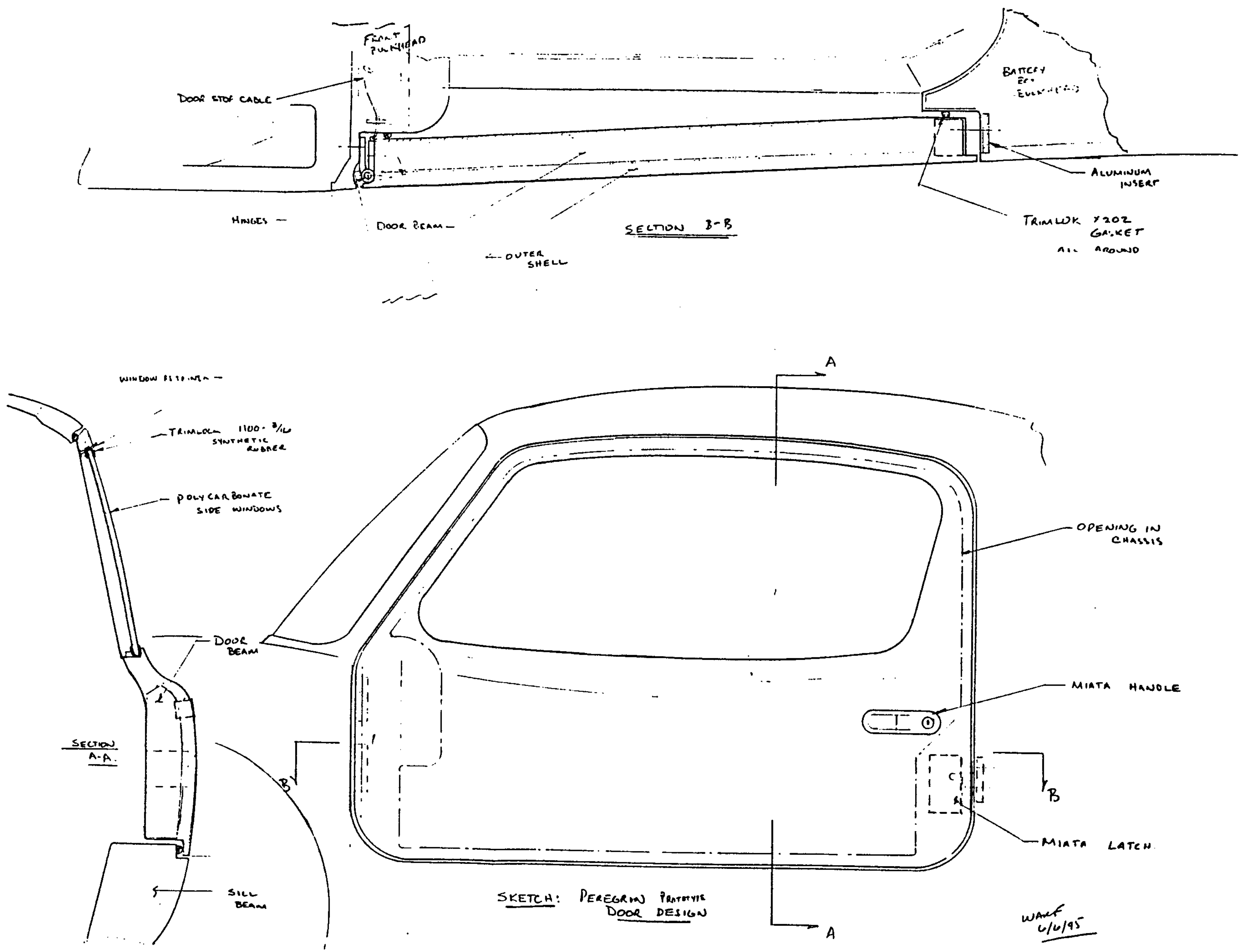
Core	Density	Designation	Shear Strength	Shear Mod.	bending stren	bend modulus	comp. stre	compressive modulus	
	lb/ft^3								
Hexcel HRH-10-1/8-1.8	1.8		40	1500	95	8000			
Hexcel HRH-10-3/16-1.8	1.8		40	1900	105	8000			
Hexcel HRH-10-3/16-2.0	2		45	2100	130	11000			
Trymer, 4 lb polyurethane foam.	4		48	600		2000			
H-30 Divinycell	2.3		50	1885	130	4060	45	2900	
H-45 Divinycell	3		70	2810	190	6080	80	5800	
Hexcel HRH-10-1/8-3.0	3		85	3500	270	20,000			
H-60 Divinycell	4		100	3190	215	8120	115	8700	
Hexcel HRH-10-1/8-4.0	4		115	4700	470	28000			
R-75 Kledgicel	4.68		144	3995	265	7234	187	8278	
H-80 Divinycell	5		145	4495	290	11600	175	12325	
Ciba, aerolam boards	5	sim to HRH-10-1/8	150	5400	620	37000			
Balsa, 6.0 lb	6		268	15600	945	325,000			
Balsa, 9.5 lb	9.5		432	23100	1870	590,000			

Item	Description	Area (ft^2)	Wt/area (lb/ft^2)	Wght (lbs)	Mass kg	Station	Water Lin	x*wt	z*wt	Category
1	Crush Block			13.70	6.213	-6	14.5	-82.2	198.65	crush
2	Nose Skin, 1/8 core, .06 skins	20.00	1.00	20.00	9.070	-4	19	-80	380	surface
3	Nose Beam	1.67	1.14	1.90	0.862	-14.5	9	-27.55	17.1	struct.
4	Suspension Beam	6.00		14.00	6.349	0	6	0	84	struct.
5	Front Bulkhead	6.00	2.25	13.50	6.122	15.5	16	209.25	216	struct.
6	shelf, front	1.77	2.25	3.98	1.807	10	17	39.84375	67.73438	struct.
7	leading beam	1.30	2.25	2.93	1.327	3.25	15	9.50625	43.875	struct.
8	Windshield			0.00	0.000			0	0	
9	A-pillars	0.44	1.59	0.70	0.317	20	31.5	13.992	22.0374	surf.
10	Edge of Roof 1.75" W!	1.84	1.59	2.93	1.327	42	39	122.8752	114.0984	struct.
11	Roof	9.50	0.70	6.65	3.016	43.5	42.5	289.275	282.625	surf
12	Side 24 hx55.13 L	22.97	1.00	22.97	10.418	41	15	941.8042	344.5625	surf
13	Door Beam	3.40	2.70	9.18	4.163	36	13	330.48	119.34	struct.
14	Glazing, doors			0.00	0.000			0	0	
15	Sills	8.05	0.64	5.15	2.336	35	5	180.2889	25.75556	struct.
16	Sill Beams (half wt of door bea	1.70	2.70	4.59	2.082	35	5	160.65	22.95	struct.
17	Floor	27.67	0.70	19.37	8.785	43	0.25	832.9924	4.842979	surf
18	Rear Body	25.50	1.20	30.60	13.878	78	20	2386.8	612	surf
19	B-box bulk head	11.67	1.41	16.45	7.462	57.5	8.5	946.1453	139.865	struct.
20	Lower block	1.85	1.00	1.85	0.838	57.5	2	106.2153	3.694444	struct.
21	Door Striker blocks			5.00	2.268	58	13.25	290	66.25	struct.
22	B-box sides	6.32	1.40	8.85	4.012	72	9	637	79.625	struct.
23	B-box back	4.37	1.40	6.12	2.773	82.5	9	504.5104	55.0375	struct.
24	Motor support	4.50	1.40	6.30	2.857	90	6	567	37.8	struct.
25	Luggage floor	10.50	0.64	6.72	3.048	82	18	551.04	120.96	struct.
		177.02		223.43	101.330			8929.919	3058.803	
							cg=	39.9669	13.69003	
	Total shell surface: 106.9 ft^2									
	Total structure surface 70.93 ft^2									

Table 8, preliminary material list, Peregrin body chassis...Page 1

Description	Material, prototype construction	Material, early production	sort.
Crush Block	245 psi crush honeycomb	corregated layup with foam, design tbd. or Honeycomb	1
Nose Skin, 1/8 core, .06 skins	.05 skin, 1/8 h80 PVC foam core	.05 skin, 1/8 h80 PVC foam core, press molded	2
Nose Beam	1"ox core, .05 skin, 8" wide, 30" long	1" H60 divinycell, no change to skins	3
Suspension Beam	ciba Aerolam 5 lb aramid panels., with .06 skin	not decided.	4
Front Bulkhead	ciba Aerolam 5 lb aramid panels., with .125 skin	not decided.	5
shelf, front	ciba Aerolam 5 lb aramid panels., with .06 skin	not decided.	6
leading beam	ciba Aerolam 5 lb aramid panels., with .125skin	not decided.	7
Windshield	Laminated safety glass (Honda 600)	Laminated safety glass	8
A-pillars	4 lb Polyurethane foam, w/ .080 glass skin, graphite reinforced.	preform in 4 lb pvc foam and S glass	9
Edge of Roof 1.75" W!	4 lb Polyurethane foam, w/ .080 glass skin, graphite reinforced.	Molded foam insert, H80 pvc properties or better	10
Roof	.05 skins over .67 thk honeycomb	.05skins over .63 thk pvc foam	11
Side 24 hx55.13 L	.05 skins over 1" ox core, or 3 lb pvc foam	.05 skins over 1" thk 3 lb pvc foam	12
Door Beam	3x10 core, 144 psi shear strength, .06 skins	Molded foam insert, H80 pvc properties or better	13
Glazing, doors	Coated Lexan, Removable		14
Sills	1" ox core, .05 skins	1" H60 divinycell, no change to skins	15
Sill Beams (half wt of door beam)	2" core, .05 skins	Molded foam insert, H80 pvc properties or better	16
Floor	.05 skins over .67 thk honeycomb	.05skins over .63 thk pvc foam	17
Rear Body	.05 skin, 1/8 h80 PVC foam core	.05 skin, 1/8 h80 PVC foam core, press molded	18
B-box bulk head	ciba Aerolam 5 lb aramid panels., with skin	Hollow cored beam, press molded with press. diaphran	19
Lower block	2x5 , 144 psi shear strength, .05 skins	Molded foam insert, H80 pvc properties or better	20
Door Striker blocks	4 lb trymer Polyurethane foam block w/ .08 glass skins.	preform in 4 lb pvc foam and S glass	21
B-box sides	ciba Aerolam 5 lb aramid panels., with .06 skin	ciba Aerolam 5 lb aramid panels (or equal), with skin	22
B-box back	ciba Aerolam 5 lb aramid panels., with .06 skin	ciba Aerolam 5 lb aramid panels (or equal), with skin	23
Motor support	ciba Aerolam 5 lb aramid panels., with .06 skin	ciba Aerolam 5 lb aramid panels (or equal), with skin	24
Luggage floor	ciba Aerolam 5 lb aramid panels., with .03 skin	ciba Aerolam 5 lb aramid panels (or equal), with skin	25
0			

Table 8, preliminary material list, Peregrin body chassis...Page 2


FRONT BULKHEAD
DOOR STOP CABLE
HINGES
DOOR BEAM
OUTER SHELL
SECTION B-B
BATTERY BOX BULKHEAD
ALUMINUM INSERT
TRIMLOK X202 GASKET ALL AROUND
TRIMLOCK 1100-3/16 SYNTHETIC RUBBER
POLYCARBONATE SIDE WINDOWS
DOOR BEAM
SECTION A-A
SILL BEAM
A
A
B
B
OPENING IN CHASSIS
MIATA HANDLE
MIATA LATCH
SKETCH: PEREGRIN PROTOTYPE DOOR DESIGN
6/6/95

Safety Characteristics, Peregrin Neighborhood Electric Vehicle
Revision 0, Body Chassis Submittal, 8 June, 1995

pages 3,8,13 & 21 replaced 6/15/95
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Introduction

Design characteristics of a vehicle which exist to make a vehicle safer, or contribute to making a vehicle safer than it would be without the particular feature are to be treated as safety characteristics. This document is prepared to provide a comprehensive accounting of design characteristics important to the saftey of the Peregrin. This document is therefore a "living document", meaning that safety issues and features will be added and this document revised as the Peregrin is developed.

Market Studies with the City-el electric vehicle have shown that a Neighborhood Electric Vehicle (NEV) should have two seats, four wheels, and should be more substantial structurally than the City-el. People have looked at the City-el and asked if it is safe. Our primary goals in designing the Peregrin are to make it look solid and safe, and to design the composite structure to protect occupants from injury in the event of accidents. The Peregrin's composite body chassis is very stiff around the passenger compartment, and features a relatively compliant nose and wing (fender) structures to absorb energy in a collision over a longer crush distance than might be realized with a uniformly stiff shell.

The primary safety characteristics considered in the design have been those related to the Federal Motor Vehicle Safety Standards (FMVSS). These have been utilized to consider the basic saftey issues, and have been taken as mandatory performance standards for the US Market.

Scope:

This Safety Characteristics document first considers each FMVSS. In the pages which follow, each FMVSS requirement is summarized, and a description of the design approach used to meet the standard is described as a "Compliance Method".

Since additional safety issues exist for electric vehciles which are not yet covered by the FMVSS , additional safety considerations are added to this document. The final section of this Safety Characteristics document deals with electric vehicle safety hazards and advisable safety characteristics which are not now required by Federal Motor Vehicle Safety Standards.

Federal Motor Vehicle Safety Standards

The Federal Motor Vehicle Safety Standards (FMVSS) provide a comprehensive

collection of requirements addressing nearly every potential safety hazard to be encountered in operating motor vehicles. Following is a numerical listing of the standards and a brief description of the design requirements derived from each standard.
Federal Motor Vehicle Safety Standards applicable to the Peregrin neighborhood electric vehicle are shown in Table 1. This document provides a brief description of the method of compliance with each standard. The Peregrin is designed to comply with each standard.

In order for Pacific Electric Vehicles (PEV) to certify the Peregrin as a compliant vehicle, verification of compliance with the standards will require physical tests of the vehicle, particularly the composite structure. In some cases, components are certified by vendors, and marked as compliant. In other cases, verification may be made by design analysis only. Table 1 gives the compliance method needed prior to commencing production, namely: "test", "analysis", or "supplier mark".

It should be noted that manufacturing processes and variation in components due to these processes must be considered when evaluating design andalysis or test results. PEV's eventual certification of the vehicle also implies the product is consistent with the verified item and method.

In many cases, the standards imply or specify loads which may be used for design. When applicable, this is mentioned with each of the FMVSS.

The description of the FMVSS is followed by a description of the design feature, or other compliance method used by PEV to satisfy the FMVSS requirement.

FMVSS 101 These standards require controls and displays to be illuminated, depicted, and located in ways which minimize diversion of the driver's attention, and thereby minimizing the chance for driver error leading to hazards to other vehicles, pedestrians, property, and occupants of the involved vehicle(s).

FMVSS 101 Compliance Method:
The design of the controls and displays of the Peregrin will comply fully with this standard. The design of the dash board and controls will be completed with the interior design milestone, and this compliance description updated at that time. Some details of the method of compliance intended follow.
12 Volt power to switches and electronics, plus control signals will be connected to the dash. Standard automotive type gages are planned. Displays will use readily available gages to the extent possible. Gages to be included are speedometer, Ampere-hour or Watt hour gages, Volt meter, Ammeter, and mandatory warning lamps. LED's will indicate the

Table 1. Saftey Characteristics. FMVSS Summary

FMVSS. 49CFR 571-				Compliance
		F-102(11)c) submittal		Verification
101	Controls and Displays	1	Interior Design	Test
102	Shift sequence, interlock, braking effect	4	Drive	Test
103	Windshield defrost	17	Glazing,defrost, HVAC	Test
104	Windshield wipers	17	Glazing,defrost, HVAC	Test
105	Hydraulic Brake System	11	Brake system Design	Test
106	Brake Hoses	11	Brake system Design	Supplier Mark
107	Reflecting Surfaces	1	Interior Design	Test
108	Lamps	2	Body Shell Design	Supplier Mark + Test
109	Tires	6	Suspension Design	Supplier Mark
110	Tires and wheels	6	Suspension Design	Supplier Mark
111	Rear View Mirrors	1	Interior Design	Test
113	Hood latches	2	Body Shell Design	Test
114	Theft Prevention	2	Body Shell Design	Test
115	VIN Number	n/a	Pre-production	Design
116	Brake Fluid	11	Brake system Design	Supplier Mark
124	Accelerator Controls	1	Interior Design	Test
201	Occupant Protection In interior Impact	1	Interior Design	Analysis + test
202	Head Restraints	1	Interior Design	Test
203	Impact Protection: Steering	9	Steering system design	Test
204	Steering Control, rearward displacement	2	Body Shell Design	Test
205	Glazing Materials	15	Glazing Design	Test
206	Door Locks and Retention	2	Body Shell Design	Test
207	Seating Systems	1	Interior Design	Test
208	Occupant Crash Protection	2	Body Shell Design	Test
209	Seat Belt Assemblies	2	Body Shell Design	Test
210	Seat Belt Assy. Anchorage	2	Body Shell Design	Test
211	Wheel Nuts, wheel discs, hub caps	6	Suspension Design	Supplier Mark
212	Windshield Mounting	15	Glazing Design	Test
213	Child Restraints	1	Interior Design	Test
214	Side Impact Protection	2	Body Shell Design	Test
216	Roof Crush	2	Body Shell Design	Test
219	Windshield Zone Intrusion	2	Body Shell Design	Test
301	Fuel System Integrity	2	Body Shell Design	Test
302	Flamability of Interior Materials	n/a	Pre-production phase	Supplier Mark
112	Head Lamp Concealment	N/A		
117	Retreads	N/A		
118	Power windows	N/A		
119	Tires, other than Pass. cars	N/A		
120	Wheels, other than Pass Cars.	N/A		
121	Air Brake Systems	N/A		
122	Motor Cycle Brake Systems	N/A		
123	Motorcycle Controls	N/A		
125	Warning Devices	N/A		
126	Truck Camper Loading	n/a		
127	Not Issued			
128	Not Issued			
129	Non-Pnuematic tires	N/A		
215	Not Issued			
217	Bus	N/A		
218	Helmets	N/A		

Table 1, Saftey Characteristics, FMVSS Summary

FMVSS. 49CFR 571-				Compliance
		F-102(11)c) submittal		Verification
101	Controls and Displays	1	Interior Design	Test
107	Reflecting Surfaces	1	Interior Design	Test
111	Rear View Mirrors	1	Interior Design	Test
124	Accelerator Controls	1	Interior Design	Test
201	Occupant Protection In interior Impact	1	Interior Design	Analysis + test
202	Head Restraints	1	Interior Design	Test
207	Seating Systems	1	Interior Design	Test
213	Child Restraints	1	Interior Design	Test
108	Lamps	2	Body Shell Design	Supplier Mark + Test
113	Hood latches	2	Body Shell Design	Test
114	Theft Prevention	2	Body Shell Design	Test
204	Steering Control, rearward displacement	2	Body Shell Design	Test
206	Door Locks and Retention	2	Body Shell Design	Test
208	Occupant Crash Protection	2	Body Shell Design	Test
209	Seat Belt Assemblies	2	Body Shell Design	Test
210	Seat Belt Assy. Anchorage	2	Body Shell Design	Test
214	Side Impact Protection	2	Body Shell Design	Test
216	Roof Crush	2	Body Shell Design	Test
219	Windshield Zone Intrusion	2	Body Shell Design	Test
301	Fuel System Integrity	2	Body Shell Design	Test
102	Shift sequence, interlock, braking effect	4	Drive	Test
109	Tires	6	Suspension Design	Supplier Mark
110	Tires and wheels	6	Suspension Design	Supplier Mark
211	Wheel Nuts, wheel discs, hub caps	6	Suspension Design	Supplier Mark
203	Impact Protection: Steering	9	Steering system design	Test
105	Hydraulic Brake System	11	Brake system Design	Test
106	Brake Hoses	11	Brake system Design	Supplier Mark
116	Brake Fluid	11	Brake system Design	Supplier Mark
205	Glazing Materials	15	Glazing Design	Test
212	Windshield Mounting	15	Glazing Design	Test
103	Windshield defrost	17	Glazing,defrost, HVAC	Test
104	Windshield wipers	17	Glazing,defrost, HVAC	Test
115	VIN Number	n/a	Pre-production	Design
302	Flamability of Interior Materials	n/a	Pre-production phase	Supplier Mark
112	Head Lamp Concealment	N/A		
117	Retreads	N/A		
118	Power windows	N/A		
119	Tires, other than Pass. cars	N/A		
120	Wheels, other than Pass Cars.	N/A		
121	Air Brake Systems	N/A		
122	Motor Cycle Brake Systems	N/A		
123	Motorcycle Controls	N/A		
125	Warning Devices	N/A		
126	Truck Camper Loading	n/a		
127	Not Issued			
128	Not Issued			
129	Non-Pnuematic tires	N/A		
215	Not Issued			
217	Bus	N/A		
218	Helmets	N/A		

use of the hand brake, high beam lights, heater, fan, flasher system, turn indicator, and low voltage.

Hand Controls: High beam, turn indicator, steering, Forward-Reverse switch (see FMVSS 102)and switches to be listed. .

Foot Controls...Accelerator, brake, proportional decelerator (regen) control, see drive design, and description with FMVSS 102)

FMVSS 102 This standard requires that the shift lever and transmission provide certain safety functions. These functions, and their comparable function in an electric vehicle, are as follows:

(a) Transmission shift patterns to be, in clockwise direction of motion of the shift lever, park (if so equipped), reverse, neutral, and forward drive. This requirement is directly applicable to electric vehicles without modification.

(b) Starter interlock to prevent engaging the starter when the shift lever is in the reverse or forward drive positions. For an electric vehicle, the shift lever lockout when the main power switch is in the "OFF" position is adequate to address this standard.

(c) The standard requires that the vehicle's transmission provide a braking effect to assist the main braking system when the vehicle is below 25 miles per hour. This particular aspect of the standard is not directly applicable to electric vehicles. This is because of the desire to allow a vehicle to coast when the accelerator control is released. This may lead to additional brake system wear, but range per charge is such a critical design aspect of an electric vehicle that additional braking effect, other than regenerative braking, is not considered beneficial. Additionally, the drive motor does not provide braking when the power to the motor is interrupted. To provide a braking effect, the power circuit must be designed to provide motor braking.

FMVSS 102 Compliance method:
The Peregrin will utilize a single speed reducing transmission with a differential which is coupled directly to the motor. The drive system will provide proportional control of regenerative braking, which is not presently addressed by the FMVSS. Because of the effectiveness of proportional regen or deceleration control in extending range and possibly also battery life, we have chosen this approach. While it may be some years before a standard is written for this feature, we believe that provided the system includes appropriate electronic safety features, proportional regen is just as controllable for the driver as proportional acceleration. The Peregrin will feature a "decelerator pedal"

driver as proportional acceleration. The Peregrin will feature a "decelerator pedal"

The forward reverse switch in the prototype will include a reverse - neutral - forward switch (clockwise). At this time, an electronic park function has not been developed. It is noted that FMVSS 105 apparently requires a "purely mechanical" parking brake, so the use of an electrically actuated brake or pawl might not satisfy the requirement for a "mechanical park ing brake" either. This will be reviewed and updated with the brake system design milestone.

There is no "starter" to interlock, however the Curtis Motor controller has a high pedal interlock on both the regen and accelerator pedal circuits to prevent the vehicle from lurching forward when the reverse-neutral-forward switch is actuated and one or the other pedal is down. A series of micro switches actuated by the pedal prevent simultaneous operation of the accelerator and decelerator pedal.

Additional details regarding compliance will be provided at the time of the submittal of the drive design-by updating this document.

FMVSS 103 This standard requires that a defrosting and defogging system be provided on all vehicles. The system(s) must meet the requirements of section 3 of SAE Recommended Practice J902, "Passenger Car Windshield Defrosting Systems", modified only to reduce the required area of the windshield to be slightly smaller than the SAE Recommended Practice specifies. Also, the defrosting function may be accomplished by heating, dehumidifying the air of the passenger compartment, or a combination of both.

The design characteristics of the defrosting and defogging system of the vehicle are:

(a) The heat output of the heating system.

(b) The defrosting and defogging damper control of air flow through the heating and defrosting system distributes warm or dehumidified air to defog the windshield.

(c) The auxiliary power system provides acceptable capacity.

FMVSS Compliance Method: The design includes an air plenum in the nose of the vehicle, which will feed air through a fan and a 400 W heating element. An additional element and fan, independently controlled will heat the foot well. design of the ducting and system will be completed with the HVAC design submittal milestone, and this standard updated. Clearly, the electrical system must have adequate capacity. The function of this system along with other systems on the vehicle will be verified by **testing**

of the prototype, and included in the final report.

FMVSS 104 This standard includes requirements for the windshield wiping and washing system. The requirements are that the system have two speeds of operation, that one operating speed be at least 45 cycles per minute regardless of engine speed, that the lower operating speed be at least 20 cycles per minute, and that the operating speeds differ by at least 15 cycles per minute. Requirements for wiped area determined according to SAE J903a are also included.

FMVSS 104 Compliance method:
At this point the specific wiper motor has not been selected, although the space for the motor has been determined. A Wiper system complying with the above will be installed in the Peregrin.

FMVSS 105 This standard specifies requirements for braking systems. Brake system stopping distance requirements are specified for various conditions of the braking system, primarily the fully operational condition and the partially failed condition.

Compliance Method for FMVSS 105: (Preliminary discussion)
The braking system is designed with two Master Cylinder circuits (front/rear) actuated be a pedal assembly capable of a 400 LB force load without undue flexing. Cast Iron disc brake rotors are fitted at each wheel, and braking is by dual piston motorcycle calipers at each wheel. These were chosen to minimize unsprung weight, and to utilize calipers which are commercially available on the prototype.

Peak system pressure will be about 500 psi, and will allow braking up to 1 g or the limits of the tires. Calculations have been done which show a deceleration of the 500 kg Peregrin at 8 m/s^2 (26.24 ft/sec^2) given a pedal force of 40 lb. and a system pressure of 363 psi. This calculation follows the method given in the Bosch Automotive Handbook, 2nd edition, page 487. A braking coefficient of C=.75 was assumed. This deceleration is higher than the 6 m/s^2 (50-0mph in < 135 ft.) peak deceleration required in Table II of FMVSS 105. Additional calculations will be undertaken and this section updated on completion of the brake system design milestone. It is noted that weight transfer calculations took into account a 1 g (9.8m/s) maximum deceleration to determine braking torque, and to estimate suspension loads.

FMVSS 105 requires a series of stops to verify the braking system does not have undue fade due to heating of the fluid, pads and rotors. The ability to fully meet this test is a function of the overall vehicle system, and will be confirmed during development of the

Peregrin. It depends on the ability of the braking system to dissipate heat, and on the pad selection. Different pad friction materials are available for these calipers. To date no heat transfer calculations have been done.

FMVSS 105 also requires a hand brake system which is actuated by purely mechanical means. Since the present Calipers do not have an external lever for the parking brake, they will have to be re-designed at least for the rear wheels to allow full compliance. We would also like to incorporate a spring in the calipers to retract them away from the rotor about .01 inches to minimize rolling friction. Data gathered during the Peregrin's development phase will be used to finalize the Caliper and rotor design.

For the Peregrin prototype, a hand brake lever will actuate the brake pedal, to allow use of the redundant hydraulic system master cylinders as a parking brake. It is unclear if this is "purely mechanical" means (fluid mechanics?) as required by FMVSS 105. Another option still under consideration is an electric actuator engaging a "park" pawl, and operated by a Park-Reverse-Neutral-Forward Switch.

FMVSS 106 This standard applies to brake system hoses.
Compliance Method for FMVSS-106:
This standard requires testing and certification by the brake hose manufacturer. Certification is in the form of compliant marking of each hose. Compliant brake hoses will be used on the Peregrin.

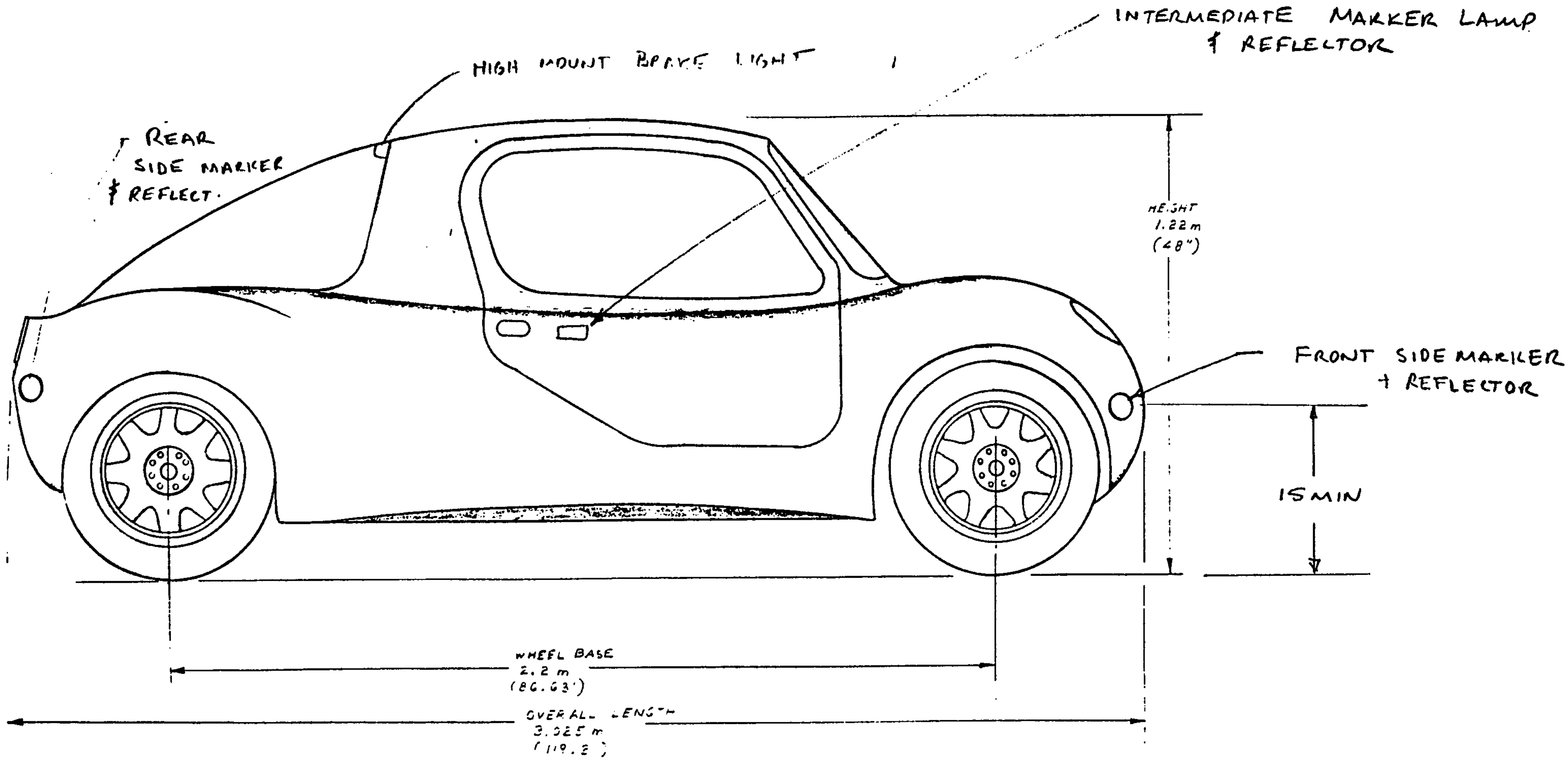
FMVSS 107 This standard applies to reflectivity of the surfaces of certain components in the driver's field of view when operating the vehicle, specifically the windshield wiper arms and blades, the inside windshield moldings, the horn ring and hub of the steering wheel, and the inside rearview mirror frame and mounting bracket.

FMVSS compliance method:
The Peregrin will comply. Compliance may be visually verified.

FMVSS 108 This standard includes requirements for lamps and reflective devices of motor vehicles. Requirements include Luminance, location, type, function, number and color of vehicle lighting.

FMVSS 108 Compliance Method
All lamps and reflectors used on the Peregrin will be marked as compliant according to the requirements in the FMVSS by the Lamp or reflector manufacturer. The function and location of these lamps and reflectors is shown in the attached figures. The type, location, number, color, and function of these items will comply with all FMVSS-108

FMVSS 108 LIGHTING REQ'D 1 of 3



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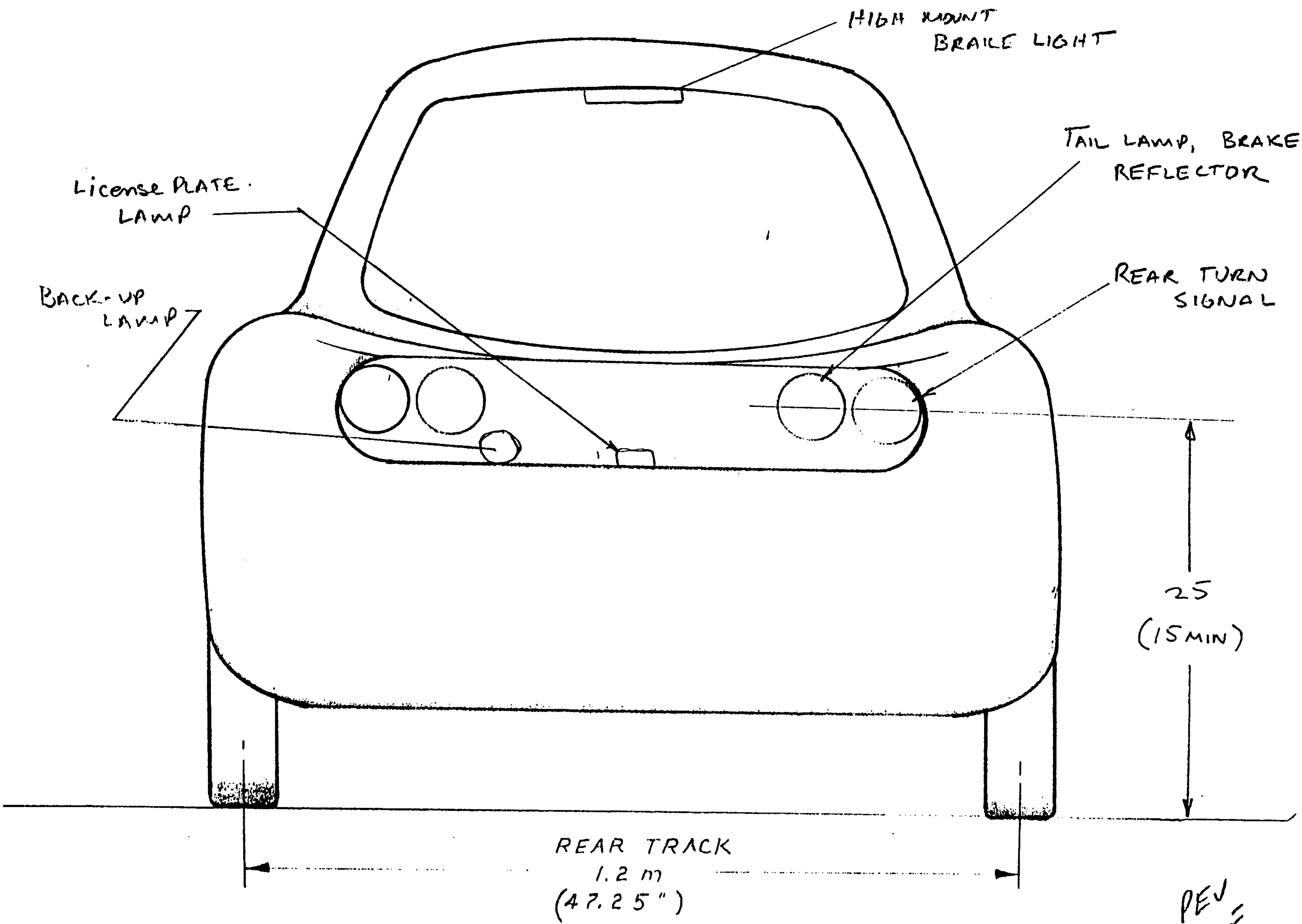
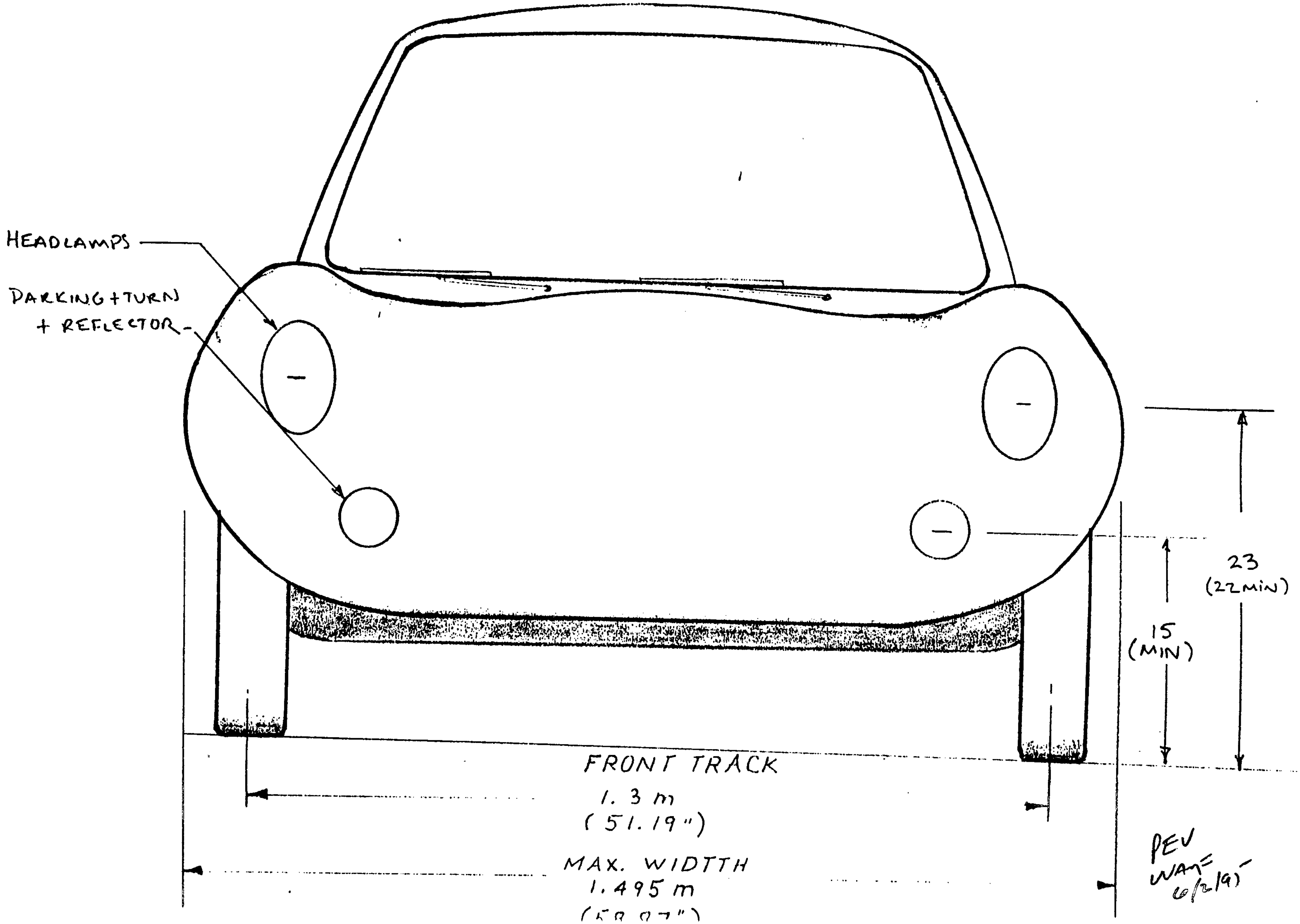
FMVSS 108 LIGHTING REQ'D 3 of 3



FMVSS 10[illegible] LIGHTING REQ'D 2 of 3



requirements.

FMVSS 109 This standard applies to tires. Requirements include marking, puncture resistance, load rating, and testing.
FMVSS 109 Compliance Method:
The Peregrin will utilize tires of an appropriate load rating, marked as conforming according to FMVSS-109 by the tire manufacturer.

FMVSS 110 Applies to tire *and rim* selection for passenger cars.

FMVSS 110 Compliance Method:
Tires and Rims have been selected based on the maximum wheel loads expected in service. Tires and Rims will be marked as compliant as required in this FMVSS on production vehicles. Because the Peregrin is a new class of vehicle, namely a NeighborhoodEV, the selection of tires and rims for use on the vehicle is presently somewhat limited. The prototype will likely use wheels and rims not yet fully compliance tested, and therefore not marked according to this standard.

FMVSS 111 This standard addresses rearview mirrors. *Requirements for mirror construction, field of view and mounting are included.*

Compliance Method for FMVSS 111:
Mirrors conforming to the standard will be used. Side mirrors on both sides of the vehicle plus an interior mirror are planned. These will comply with the FMVSS. Field of view and area will be confirmed on the prototype Peregrin.

FMVSS 112 This standard applies to head lamp concealment devices, *which are not used on the Peregrin.*

FMVSS 113 The subject of this standard is hood latch systems. *Redundant or two position latching is required if the hood is in the forward field of view.*

FMVSS 113 Compliance Method:
There will be a small access panel in the front of the Peregrin, to provide access to the back of the dash, and to the brake fluid reservoirs. The latching of this access cover will conform to FMVSS 113.

FMVSS 114 The general subject of this standard is "theft protection". The standard intends to reduce the incidence of unauthorized operation and vehicle rollaway incidents. *In summary the requirements include a key lock on the steering wheel and ignition, and if an automatic transmission is present a lock in Park feature. A warning bell is required if the key is left in the key switch with the door open.*

FMVSS 114 Compliance method:
The intent of this standard might be best met with an electronic brake or parking pawl. The release of the pawl or brake would require both key on and "Park-Reverse-Neutral-Forward" switch activation. The specific compliance method for this standard is to be determined. The prototype will not fully comply with the standard, however the requirements will be incorporated during development.

FMVSS 115 The subject of this standard is vehicle identification numbers. Through standardization, the accuracy and efficiency of vehicle recall campaigns is intended to be improved and the incidence of accidents decreased.

FMVSS 115 compliance method:
For the earliest production of the Peregrin identification plates conforming with 49 CFR 567 and FMVSS (49 CFR 571-) 115 will be designed and affixed to each vehicle. The prototype will not conform to this standard, however any vehicles sold must comply prior to sale.

FMVSS 116 This standard places requirements on brake fluid and its testing and labeling.

FMVSS 116 Compliance Method:
conforming brake fluid, furnished in containers which are marked according to this standard will be used in the Peregrin.

FMVSS 117 This Standard applies to retreaded tires. There is no intent to use retreaded tires *on the Peregrin, and thus this standard is not applicable.*

FMVSS 118
The subject of this standard is power operated windows. There is no intent *to*

utilize power windows in the Peregrin, so this standard is not applicable.

FMVSS 119 This standard addresses tire requirements for vehicles other than passenger cars, *and thus it is not applicable to the Peregrin.*

FMVSS 120 Tire selection and rims for *vehicles other than passenger cars* is the subject of this standard. *This standard is therefore not applicable to the Peregrin.*

FMVSS 121 This standard applies to air brake systems. As such, it is not used on the Peregrin. *This standard is therefore not applicable to the Peregrin.*

FMVSS 122 Applies to motorcycle brake systems.
This standard is therefore not applicable to the Peregrin.

FMVSS 123 Applies to motorcycle controls and displays.
This standard is therefore not applicable to the Peregrin.

FMVSS 124 This standard applies to accelerator control systems. The standard requires that the accelerator control return to the idle position, within a specified time, when no force is applied to the accelerator pedal, or when the accelerator control is severed or disconnected. The time limit is one second for this vehicle. The safety characteristic applicable to this standard is the accelerator return spring force for each of the two required return springs with which the accelerator is equipped.

FMVSS 124 Compliance Method: Both Accelerator and Decelerator Pedals shall have redundant springs to return the pedals to their off position. These mechanisms will comply with the standard.

FMVSS 125 This standard applies to reflective warning devices to place on the roadway to warn of a vehicle stopped in the roadway. *This standard is not applicable*

to the Peregrin. A flasher warning lamp system will be incorporated to accomplish this function when the emergency flasher is actuated.

FMVSS 126 Truck-camper loading is the subject of this standard. *This standard is not applicable to the Peregrin.*

127 Number not issued.

128 Number not issued.

FMVSS 129 Applies to non-pneumatic tires. *This standard is not applicable to the Peregrin.*

130-200 Numbers not issued.

FMVSS 201 The title of this standard is "Occupant Protection in Interior Impact - Passenger Cars". The standard applies to trucks with a Gross Vehicle Weight Rating of 10,000 pounds or less, as well as other vehicles. The requirements relate to instrument panel design, seat back design, interior compartment door design, sun visor design, and armrest design.

The intent of the standard is to prevent injury in the event of an accident, through contact of the passenger or driver with vehicle interior surfaces.

FMVSS 201 Compliance Method: Interior surfaces shall be designed to meet this standard. These requirements will be taken into account in the Interior Design milestone, and this section updated at that time. It is noted that the layout of the Peregrin has provided a significant "rundown" length forward of the driver and passenger, to help prevent contact with the Windshield and the Dash, providing seat belts are worn.

FMVSS 202 This standard requires head restraints on passenger cars and, on models produced after September 1, 1991, on multi-use passenger vehicles, trucks and buses with a gross vehicle weight of 10,000 pounds or less. *The intent of the standard is to limit the frequency and severity of neck injury in rear end and other collisions. The head restraint shall be capable of a 200 LB load prior to failure of the seat, seat back, or seat mounting. The head restraint shall also prevent rearward angular displacement of the head of greater than 45 degrees from the torso line.*

FMVSS 202 compliance method:
Seats incorporating a head restraint compliant with the above will be used. The above 200 LB load shall be considered in design of the seat adjustment mechanism. This section will be updated with the interior design milestone.

FMVSS 203 This standard provides the requirements for steering control assembly construction and the seat belt requirements for vehicles which do not have complying steering controls. The standard requires that the steering control not result in greater than 2500 pounds of force to a standard "body block" in a 15 mile per hour impact test. It also requires that steering controls not have any detail of construction that "can catch the driver's clothing or jewelry during normal driving maneuvers". *This standard does not apply to vehicles which conform with FMVSS 208.*

FMVSS 203 Compliance Method: The prototype Peregrin will utilize type 2 lap belts conforming to FMVSS 209 and 210. In addition, a collapsible steering column will be used in the prototype. This section will be updated with the steering design milestone.

It is noted that the Peregrin is designed to be compliant with FMVSS 208, as discussed later in this document. The prototype Peregrin, and some early closed facility market production will be compliant with FMVSS 203, pending confirmation of FMVSS 208 compliance. . Installation of an Air Bag is required for full compliance with FMVSS 208, however the dynamic response of the vehicle structure must be well characterized prior to air bag specification.

FMVSS 204 This standard includes the requirements for steering control rearward displacement during a 30 mile per hour frontal impact collision test. It requires that the upper end of the steering column and shaft (in the passenger compartment) be displaced no more than 5 inches in a horizontal rearward direction parallel to the longitudinal axis of the vehicle, and relative to an undisturbed point on the vehicle.

FMVSS 204 Compliance Method: The upper steering column is rigidly mounted to the front bulkhead to prevent rearward displacement, and to prevent rotation of the steering column which could affect air bag effectiveness. The expected rearward deflection of this bulkhead structure during an FMVSS 208 30 mph impact is about 0.091 inches.

The steering rack is mounted in the front crush zone, however it's mounting is designed to bend the steering shafts near the end of the impact, without disturbing the mounting

of the upper shaft or affecting rearward displacement of the wheel..

This section will be updated at the Steering design milestone.

FMVSS 205 This standard provides the requirements for motor vehicle glazing materials. *The standard refers to ANS Z-26, which categorizes glazing into "item n" categories, and which specifies tests and marking requirements for each category, along with permissible use locations.*

FMVSS 205 Compliance
The intent of this standard is to assure that glazing materials used in motor vehicles remains appropriately transparent such that visibility isn't impaired, to prevent injury in impacts, and to prevent ejection of the passengers. The Peregrin will comply with the requirements of FMVSS 205.

The Peregrin will utilize an ANS Z26 Item 1 laminated safety glass windshield. The windshield is from a Honda 600, and is marked as compliant.

Side windows in the Peregrin will be Item 4 or Item 5 rigid plastic glazing (Polycarbonate). These windows are easily removable by the vehicle operator from the inside of the vehicle, and as such are compliant with FMVSS 205. Since they are tough polycarbonate, they will be relatively "springy", compliant in a deflection versus load sense. Also, since they install against a flange in the door from the inside, they satisfy the occupant retention needs expressed in the standards.

The rear hatch of the Peregrin is to be fabricated in rigid plastic, either toughened acrylic or coated polycarbonate. The rear window material will comply with Item 4 or 5 of ANS Z26. The rear hatch will be removable so the Peregrin can function like a small pick-up when needed.
This section will be updated on completion of the Glazing Design milestone.

FMVSS 206 Door Locks and Door Retention Components.
This standard requires that door latches and hinges meet certain strength requirements, to assure the doors are retained during an impact, to minimize the likelihood of occupants being thrown from the vehicle.

The requirements include the following:
All doors except readily removable doors have two latch positions.
Door Latch and Striker Plate, when latched, are capable of remaining latched under a longitudinal load of 2500 lb., and a transverse load of 2000 lbs. Test methods and apparatus are shown in SAE j 839 (b){3:34.02}. The door striker plate and latch must

also withstand a load of 30 g, however the door mass is about 25 lbs, and the resulting load in this case is about 750 lbs.
Hinges are tested similarly, although SAE J934 allows the above loads to be shared by a pair of hinges, or uniformly loaded along the length of a piano hinge.

FMVSS 206 Compliance Method Door mounting to the composite structure of the Peregrin is designed to meet the requirements of FMVSS 206. Door latches are from the Mazda Miata, and are expected to comply. Hinges are made specifically to fit the Peregrin, for mounting to the composite structure, and to sustain the above design loads.

FMVSS 207 This standard applies to vehicle seats. The seat plus mounting shall be capable of withstanding a load equal to the 20 times the weight of the seat (about 15x20=300lbs)in a forward or rearward direction, at any adjustment position. The adjusted position shall not change as a result of the loading. the load shall also be applied to produce a 3300 in-lb moment about the Seating reference point, (about 330 lb at 10 inches from seat bottom face).

FMVSS 207 Compliance Method
Seat adjustment needs must be finalized before finalizing seat mounting. The mounting structure will be designed to accommodate adjustment needs and to withstand the above loading. This section will be updated along with the interior design milestone.

FMVSS 208 Occupant Crash Protection:
This standard requires that the certain injury criteria are not exceeded, when measured in a frontal barrier test at up to 30 miles per hour into a rigid barrier, at any angle up to 30 degrees from perpendicular, using standard, instrumented test dummies. The injury criteria is summarized as follows:

1. Head Injury Criteria < 1000
2. Maximum acceleration of the upper thorax does not exceed 60g's except for intervals whose cumulative duration is not more than three (3) milliseconds.
3. The compressive force transmitted axially through each upper leg shall not exceed 2250 lbs.
4. The sternum to spine compression is less than 3".
5. All parts of the Hybrid III Test Dummy shall be retained within the outer boundary of the vehicle body.

For design, the vehicle should be considered to be loaded to its GAVWR.

Although type 2 seat belts are required by this standard, the test may be performed without seat belts on the dummies. This precludes the use of Eurobags, which are smaller and lighter. Eurobags might be beneficial in small electric vehicles, but would require passengers be belted to control the trajectory towards the smaller European bag.

In the event a manufacturer chooses to meet this standard using devices other than seat belts and air bags, two additional tests are required. These are a side impact and a dynamic roll over test.

Air bags for both driver and front seat passengers are required on essentially all cars after September 1, 1996.

FMVSS 208 Compliance Method:
The Peregrin is designed as a composite monocoque chassis which is particularly rigid around the passenger compartment, and which incorporated more flexible curved structures for the fenders, and a crush block bonded in the nose of the vehicle.

The crush block has so far been modeled as 250 psi crush strength Hexcel Honeycomb, possibly Aluminum Commercial Grade ACG-1/4. The block is presently sized as a 7.5 inch high 28 inch wide block when viewed from the front. In a side view, the top edge is tapered, increasing in thickness from front to back, where it is bonded to the body shell. This is ideally to avoid a sharp peak at the onset of column buckling of the Honeycomb. Space is available in the nose of the vehicle for other crush block concepts, and additional work in this area will be performed during development. A combination of inexpensive foam and composite members which deflect under the impact load can be designed, however this design would require extensive analysis and testing, and the honeycomb system is well characterized. A special crush block design could improve deceleration properties in angular frontal impacts, by increasing the energy absorbed in bending and crushing the wings.

The crush block is supported by a bulkhead structure which extends from the back of the crush block to the dash sub-structure, even with the front edge of the doors. This bulkhead has been designed to carry the load imparted by the crush block with minimum deformation, and without exceeding the elastic limit of the composite lamina and the shear stress in the core.

The expected deflection of the crush block is 12 inches (300mm) providing for a nominal deceleration of 40 g's or less under the FMVSS 208 frontal barrier impact. The intent of this limit is to provide sufficient compliance (deflection under load) of the front of the

vehicle to limit the loads to and deceleration of the passengers and vehicle components to less than 60 g for the maximum 3 milliseconds cumulative as required by the standard.

It is noted that because of the short nose of the vehicle, the wheels and tires are deflected rearwards during the crush. In the event the tires are pointed approximately straight ahead during impact, a crush area at the back of the wheel well, into the under door sill beam portion of the structure is provided behind the tires to allow them to displace sufficiently. In the event the tires are turned, the intent of the design is that the steering arms and or steering rack mounting fail, and allow the wheels to turn and rotate out of the crush zone. It is noted that the peak front suspension load used in the design is 1764 lb, or 3 times the maximum wheel load. The expected crushing force in the impact is on the order of 50,000 lbs over the 12 inch deflection.

All other structures are designed to support their attached components at a deceleration of 60 g. The seat belt anchorage design intent is to take 80 g, however this appears to be in excess of the requirements, and must be confirmed by testing.

The battery box bulkhead has received significant attention, since the 400 lbs of batteries will be supported at this bulkhead during the design value 60 g deceleration. This hollow bulkhead is designed to withstand a uniform load of 1.1 times the battery mass at 60 g deceleration without exceeding the elastic limit of the lamina and without a shear failure of the core. The center of the beam acts as an air plenum to feed cooling air to the batteries and drive from ducts on the side of the Peregrin.

FMVSS 209 This standard applies to seat belt assemblies. Requirements for mounting hardware, belt breaking strength, belt elongation, locking and extension to fit 5% female to 95% male occupants are covered. Load capability of the anchor points for the type 2 belts is specified as 1500 lbs for the shoulder belt, 2500 lbs for the lap belt, and 3000 lbs for the common anchor. Attachment bolts shall have an ultimate strength of 9000 lbs, and all other hardware shall have an ultimate strength of 6000 lbs. Marking requirements for belt and belt mechanism manufacturers is provided.

FMVSS 209, Compliance Method: Seat belt anchor inserts have been designed for bonding into the composite structure. These inserts are designed to take a 17,600 lb load (80 g, 100 kg occupant) applied to the belt. Pull out of the insert from the composite is estimated at 11,300 lb at each anchor. Seat belt hardware which is marked as conforming to the standard will be used.

FMVSS 210 Standard No. 210 deals with the anchorage's for seat belt assemblies.

The basic requirement is for the seat belt anchorage's to be able to stand a load of 5000 lbs applied to the belt. The standard also provides location limits for the shoulder belt anchor.

FMVSS Compliance Method:
The design of the Peregrin is compliant, as these requirements have been taken into account. Please see discussion for FMVSS 209.

FMVSS 211 This standard addresses wheel nuts, wheel discs, and hub caps.

FMVSS 211 Compliance Method: This standard has not yet been considered, however it will be reviewed and this section updated with the suspension design milestone.

FMVSS 212 Standard No. 212 deals with windshield mounting requirements. The requirement is that not less than 75% of the windshield periphery must be retained in the windshield mounting following a 30 mph frontal barrier collision (50% in a vehicle with passive restraints).

FMVSS 212 Compliance Method:
A calculation to determine the strength of the bond of the glass to the composite structure shows the bond strength required is on the order of 30 psi for a 60 g impact. Because of the stiffness of the composite structure around the periphery of the windshield, separation should be minimal in an impact. Selection of the bonding material will be made based on the final coatings and bonding compatibility, with a 50 psi system capability as a goal. It is noted that carbon fiber reinforcement is used around the windshield and across the top of the door to stiffen the structure around these openings. The estimated cost impact to the production of the body using carbon in addition to glass fibers for this portion of the structure is about $150.00. More comprehensive modeling of the structure could reveal that the Carbon is not required, however experience with the prototype, including measuring deflection under load of the opening may be less costly than a sufficiently detailed finite element analysis.

FMVSS 213 This standard applies to child restraint systems.

FMVSS 213 Compliance: The Peregrin will be fitted with additional hardware to accommodate Child restraints. A new standard "ISOFIX" has been proposed to provide uniform child seat restraint and mounting. Although not included in the prototype effort,

this standard will be considered and incorporated in the Peregrin if possible.

FMVSS 214 Side Impact Protection

This standard specifies performance requirements for protection of occupants in side impact crashes. Two tests are specified.

First a load deformation test of the door itself applied near the center of the door, and 5" above the lower edge of the door. The load is applied by a 12" diameter cylinder, traveling 1/2" / second or less for up to 18". Seats are removed from the vehicle, and the vehicle is tied down during the test. The average load over the first six inches of deformation must be greater than 2250 lbs, and the peak average load is 3.5 times the vehicle curb weight (3500 lbs for the Peregrin).

The second test involves a moving barrier side impact utilizing a Honeycomb bumper structure. The 3015 lb barrier is traveling at 33.5 mph when it strikes the side of the vehicle. Instrumented dummies are used to verify that the Thoracic Trauma Index (TTI(d)) does not exceed 90g, and the Peak Pelvic acceleration does not exceed 130g. In addition, the doors must remain latched, and the hinges must remain intact. The vehicle is not tied down.

FMVSS 214 Compliance method.

Door Load deformation test:

Significant effort has been made to assure the door structure is strong enough to take this loading. The door includes a side impact structure which is 3 inches thick, and which is integral with the door composite structure. This beam overlaps the front bulkhead and the battery box bulkhead. These provide a rigid support for the ends of the beam. The door also overlaps the body shell structure essentially from the glazing line down and around the edge of the sill, and back up to the A-pillar.

The composite is stressed below it's elastic limit and below the shear limit of the core structure when loaded as specified by the 12" diameter cylinder at a load of 3.5 times the Peregrin Curb weight of 1000 lb. Deflection of about 1.25 inches is predicted by modeling the door beam as a simply supported beam spanning from the front bulkhead to the battery box bulkhead.

Moving Barrier test: Because the deformable barrier is 66 inches wide, it will contact essentially the full side of the Peregrin. The rigid sill under the door and the front and battery bulkheads will take the load, and the barrier is expected to bump the light Peregrin sideways. The design goal is to make the Peregrin as "hard shelled" and stiff in this load case as possible. Dynamic analysis of this crash event has not been performed as of this

writing.

215 NOT YET PUBLISHED

FMVSS 216 This standard addresses roof crush resistance for passenger cars. The requirement is that the roof be capable of sustaining a load equal to 1.5 times the vehicle curb weight applied at the outer forward edge of the roof, without deflecting more than 5".

FMVSS 216 Compliance method.
The Peregrin has been designed to take a point load of 1500 lbs at any point on the roof, without exceeding the elastic limit of the lamina or the shear strength of the core. Expected deflection in this test is about 1.25". The edge of the roof at the door openings, and the windshield surround are thickened to provide additional reinforcement around the opening. This reinforcement is similar the reinforcement of openings approach used in pressure vessel design, except with composites a layer of higher stiffness Carbon fiber is placed near the maximum fiber distance around the thickened opening reinforcement section.

217 This standard addresses only bus window retention and release requirements and is not applicable to The Peregrin.

218 This standard applies only to motorcycle helmets. It is, therefore, not applicable to conversion vehicle safety. Not applicable to The Peregrin.

FMVSS 219 The standard requires design of hood and other components of the front portion of the vehicle chassis and body such that no part of the vehicle may contact a specified portion of the vehicle windshield during a 30 mph crash test. Paint chips and small flakes or pieces of material generated during the crash test, but which would not be expected to penetrate the windshield are not meant to be restricted by this standard. The design characteristics of vehicles which can affect compliance with this standard are basically: (a) the integrity of the hood attachment hardware to the vehicle chassis or body; and (b) the structural design of the vehicle forward of the doors, and attachments to the structural members.

FMVSS 219 Compliance
The only component of the Peregrin which might contact the specified windshield area is the access panel which must be removed to access the brake fluid reservoirs. This small, "hood" like panel will be retained by lockable latches and an overlapping lip. The design will prevent the hood from contacting the windshield in the FMVSS 208 30 mph barrier crash test.

220, 221, 222 These standards apply only to school bus safety features. They do not apply to the Peregrin.

FMVSS 301 This standard limits the liquid fuel spillage during a frontal, rear, or side impact test as specified in FMVSS 208, the volume of fuel spilled shall not exceed 1 oz by weight per minute. In addition, the above mass rate of fuel spillage shall not be exceeded when the crashed vehicle is attached to a turntable base, and rotated around it's longitudinal axis in 90 degree increments. Although this standard applies to fuel, NHTSA personnel have conveyed to me in personal conversations that they intend this standard apply to battery electrolyte.

FMVSS 301 Compliance Method.
All of the batteries in the Peregrin are contained in a compartment aft of the seating position and in front of the rear axle center line. The battery box is ventilated by air flowing from the side of the vehicle through a plenum formed by the battery box bulkhead, and then outward through the rear of the vehicle below the cargo bed. The underside of the cargo bed is fitted with a seal intended to prevent battery acid or vapors from entering the passenger area. Batteries are fastened down to the floor of the battery box, bearing against the forward bulkhead.

The design goal is to enable use of flooded batteries by containing battery electrolyte in the battery box during a roll over. Limiting the electrolyte spillage to 115 cc/min of 1.2 sg battery acid is likely to be difficult after a crash event.

The back-up to this solution is to use sealed batteries. The battery compartment will protect the batteries from mechanical damage, and will facilitate temperature management without large heaters.

The Peregrin also features a safety switch which actuates the main contactor to open the main battery power circuit in the event of an impact.

FMVSS 302 The requirements of this standard deal with occupant compartment material flammability, primarily for prevention of fires initiated by matches or cigarettes.

FMVSS 302 Compliance will be considered in the interior design of the prototype. Full compliance will be achieved in early production vehicles.

SAFETY CHARACTERISTICS NOT ADDRESSED BY STANDARDS

A. Electrical Propulsion Power System -

The propulsion power for the Peregrin is provided by 6 twelve volt deep cycle batteries. The power to drive the motor is controlled by a Curtis controller housed at the rear of the battery compartment. Some notes about the 72 V system follow.

* The propulsion power system, as well as its on-board charging system, is ungrounded and electrically isolated from the vehicle chassis and body. The body chassis of the Peregrin is non-conductive composite.

* The positive side of the power supply is generally separated from the negative by a distance of at least 18".

* Connections in the propulsion power system are either enclosed within a housing or covered with an insulating material to prevent inadvertent contact by maintenance tools or personnel in contact with the vehicle.

* To essentially eliminate the chance of electrocution, the propulsion power system is equipped with a normally open main contactor, which opens the 72 Volt circuit when it's 12 volt coil is switched off by the ignition switch or the kill switch. The DC-DC converter is parallel to this normally open main contactor, but can be switched off by a separate switch. Inertia switches on both the main power contactor and the DC-DC converter power circuit interrupt these circuits in the event of a collision. This allows maintenance or display of the vehicle without concern for personnel injury at those times

which are considered to be most hazardous to personnel. These times are:

(1) During maintenance or while on display with the hood and battery compartments open;

(2) In the event the propulsion power circuit becomes shorted because of damage to the vehicle.

(3) In the event of a collision, when emergency personnel or others providing assistance to accident victims, may inadvertently come in contact with exposed connections within the propulsion power circuit.

The design characteristics which are critical to proper operation the high voltage system are:

(a) The force of a collision must be sensed within 50 milliseconds or less of initial contact.

(b) Relays must fail to their safe position.

(c) The location of manual switches should be such that they are accessible by the driver and/or maintenance personnel without difficulty, and other switches must be located to assure reliable operation.

(d) Fuse protection which limits current to 250 amperes maximum through the main power fuse.

B. Charging System -

The electrical safety of the charging system to be installed in or used on electric vehciles must include certain safety features.

To ensure that the potential for electrocution during charging is minimized, provision of a ground fault interruption device adjacent to the charging receptacle is required.

The accidental operation of the vehicle when connected to its charging cable is an

interlock to prevent vehicle operation when connected to a charging power source is included.

C. Battery Retention and Containment -

Batteries are contained in a battery compartment designed to contain the batteries in the event of a collision. The batteries bear against the front bulkhead, and are fastened to the floor of the battery containment compartment. See discussion for FMVSS 208 and 214.

D. Battery Ventilation -

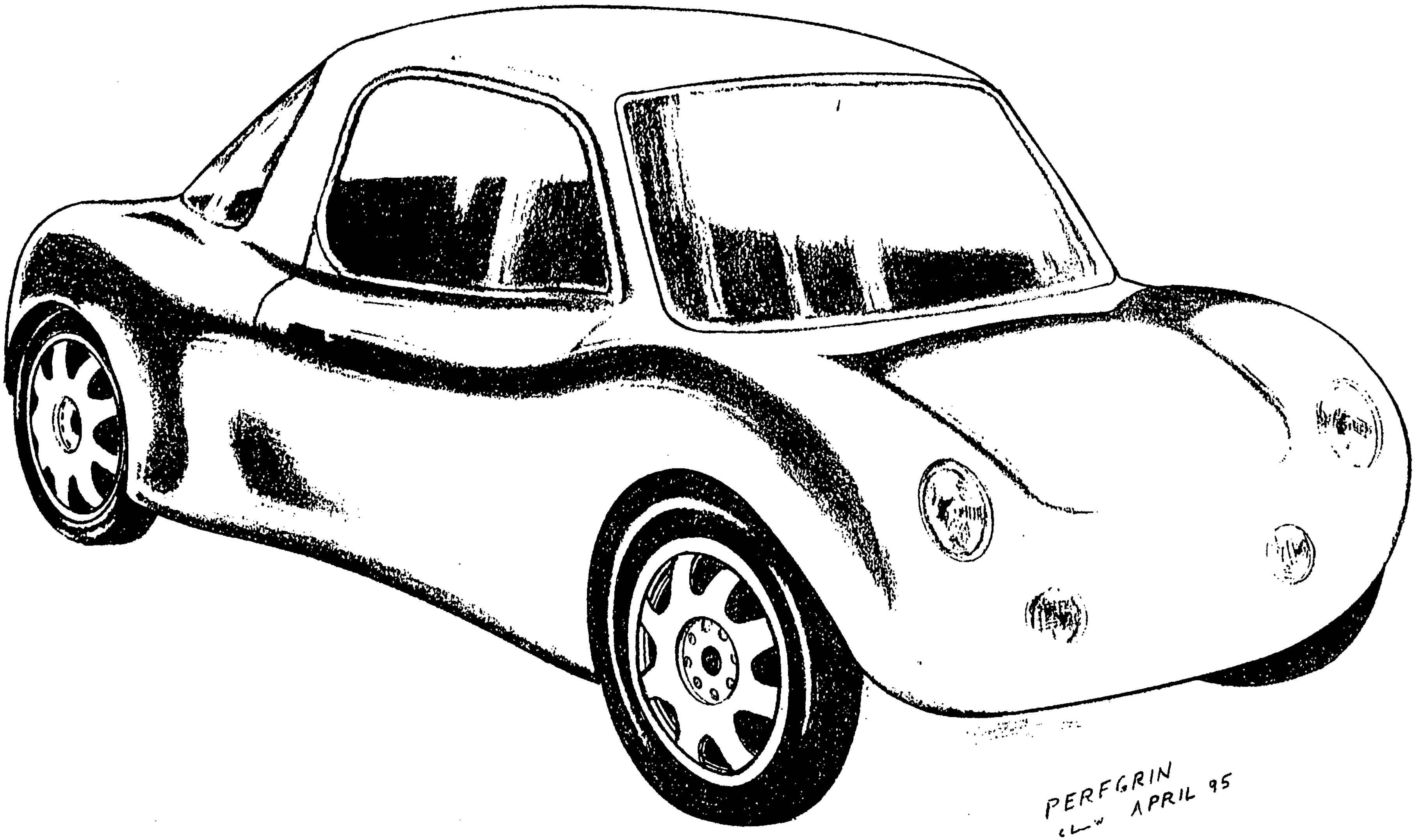
The generation of hydrogen gas during charging is the primary explosion and fire hazard remaining in the conversion vehicles. Hydrogen is also produced at other times which should be addressed by design.

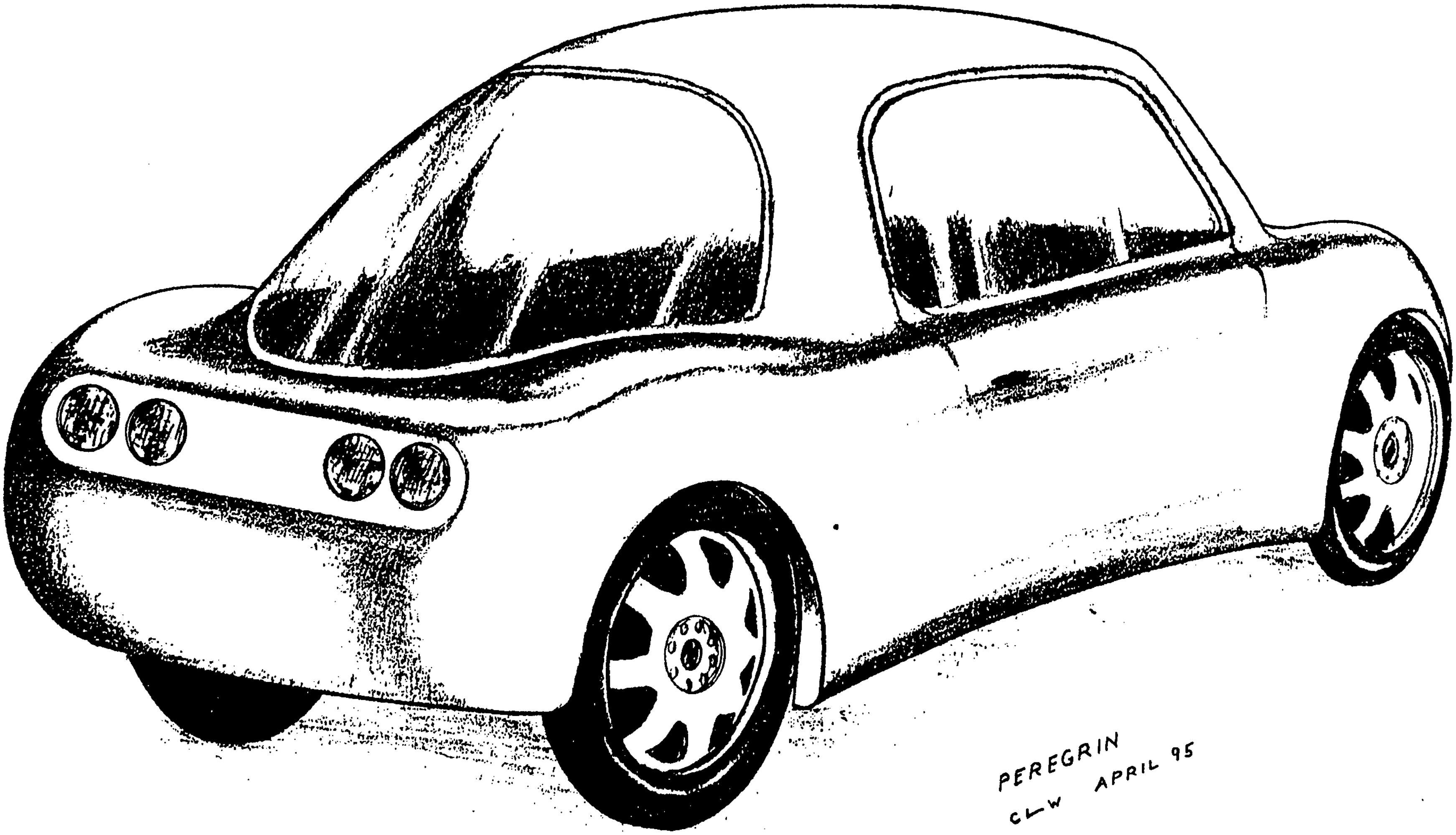
To ensure adequate ventilation from the battery boxes is achieved, the battery containment is provided with an air inlet in the front of the containment, and an outlet near the rear top of the battery containment. There are also holes with removable plugs in the floor of the containment to allow for drainage during cleaning of the tops of each battery pack without removing them from the vehicle. The ventilation of the battery compartment is such that liquid electrolyte would leak from the vehcile as far from the passenger compartment as possible, and such that the volume of electrolyte leakage is minimized.

E. Vehicle Performance -

The performance of vehicles must be considered to be a potential safety hazard due to creation of hazards to other vehicles when an obstruction or interference with the flow of traffic is caused by a faulty or low performance vehicle. Included in a vehicle's performance characteristics is its ability to climb grades, or grade ability.

The Peregrin has sufficient power to accelerate from 0-35 in ten seconds, and thus should be able to accelerate with traffic. The Peregrin will slow climbing steep hills, however it will be able to maintain 25 mph up to a 8% grade. The unsprung weight of the Peregrin is low, and the suspension travel relatively long to assure a good ride and good handling and braking on all surfaces, at all payloads within the GAVWR.


PERFGRIN
APRIL 95



PEREGRIN
CLW APRIL 95

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Peregrin

a prototype by Pacific Electric Vehicles

Two passenger, four wheeled Neighborhood Electric Vehicle

Range: 30-40 miles (lead acid batteries)

Top Speed: 45 mph

Acceleration: 0-35 mph in 10 seconds

Drive: 6 kW nominal, 15 kW peak...Brush DC Motor and Controller with regenerative braking. Direct drive through a differential with 5.6: 1 total reduction. Maximum Grade 22% with 100 kg load.

Energy use: <100 DC, <200 AC W-h/mile (about 2 cents per mile)

Curb Weight: 450 kg
GAVWR: 700 kg
Battery Mass: 180 -200 kg

Battery Replacement Cost: $600 (lead acid batteries)

Construction: Composite Unibody with rigid passenger enclosure and crushable structures
Wheel Base: 2.2 m (86.63 inches)
Track F/R: 1.3 m / 1.2 m (51.19" / 47.25")
Height: 1.22 m (48 inches)
Overall Length: 3.025 m (199.2")
Width: 1.495 m (58.87")
Cargo Capacity: 8 cubic feet (.226 m^3), 220 lbs (100 kg) with 2 passengers
Brakes: Hydraulic Discs at each wheel
Designed to meet applicable Federal Safety Standards 6/8/95

Persport vs City-el Comparison.

21 June, 1995

Neighborhood Electric Vehicle Product Test and Development Project

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REPORT: Persport vs City-el Comparison.
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Purpose: Recently two City-els were converted to a 4 wheel configuration. These converted vehicles are referred to as Persports. The Persports were converted from City-els SO3344 and SO3574. The 4 wheel conversion consists of a double A arm suspension for the front wheels and changes in the steering gear and shaft to accommodate the new front suspension. The purpose of this testing was to evaluate the differences between the City-el and the Persport so that the advantages and disadvantages of a 4 wheel NEV could be determined. This information should be useful for designs for other 4 wheel NEVs. This testing also included an experimental regenerative braking system which was evaluated to see what improvements regen might provide an NEV.

Scope: City-el 4133 was used as the City-el control vehicle during this testing, and Persport 3574 was used as the test vehicle. City-el 4144 with the experimental regen system was used to evaluate the effects of regen. Testing began by qualitatively testing Persport 3574 to find the best toe in and tire pressure settings. Once that was complete, roll down tests on the Persport were done to determine the coefficient of drag times area (CdA) and the rolling resistance (Croll). Roll down data for the City-el was taken from previous reports on the coefficient of drag and rolling resistance. Road tests on all 3 vehicles were also done to compare performance differences between the City-el and the Persport. McClellan AFB's EV Course served as the road course for this phase of testing. These tests also provided information on the differences in energy use between the City-el, Persport, and City-el with regen. The data from the on road tests was then used to compare actual power use with the power use predicted by mathematical models. These mathematical models used information from the roll down tests and other sources. Most data for all the above tests was taken using the City-el Data Acquisition System (DAS).

Conclusions: For the most part, the differences between the City-el and the Persport were small indicating that a 4 wheel NEV is just as viable as a 3 wheel NEV. Tire pressures were changed slightly for the Persport. Front tires were 36 psi instead of the City-el 35 psi, and the rear tires were 39 psi instead of the City-el 40 psi. These changes seemed to provide the Persport with the best handling. Both Persport 3574 and City-el 4133 were tested with the motor in the series wound configuration so that higher top speeds could be attained. The higher speeds were necessary to evaluate handling differences. Roll down tests indicate that the addition of the front suspension increased the coefficient of drag times frontal area (CdA) to 0.66 for the Persport. Previous testing has shown the City-el to have a CdA of 0.47 and a coefficient of rolling resistance (Croll) of 0.0136. The Persport's rolling resistance was found to be 0.0120. This is a surprising result. Since the Persport has 4 wheels, a higher rolling resistance would be expected. The reason for the lower rolling resistance is unknown at this time. Road testing for all 3 vehicles was performed on McClellan AFB's EV Course and utilized the City-el Data Acquisition System (DAS) to collect the data. This course was carefully characterized using distances from turn to turn, weather information, road direction information, and hill information from a 2 foot contour map. The Persport used 18% more energy per mile

compared to the City-el when tested on this course. City-el 4144 with the regenerative braking system improved the energy used per mile by 5% compared to the stock City-el. The Persport showed an improvement in handling over the City-el. Cornering speed was up by as much as 4.5 mph, and stability through the corner was significantly better. The City-el had better straight line stability and on-center feel though. This could probably be fixed with further development on the Persport's prototype suspension. The power equations developed for the vehicles are given in the last section of this paper. These equations predict the power use of the vehicles quite well considering the number of variables and the error present in each variable. Under cross wind conditions though, the model does not predict the power use as accurately.

Although the Persport has been shown to be a viable NEV, it would be interesting to do further tests. Testing on the Horlacher vehicles, for instance, would be helpful in evaluating the effects of wider tires, larger bodies, and more mass on the performance of an NEV. As an NEV, the Persport trades slightly higher energy use for much improved cornering. However, some of this energy use loss could be offset through the use of regenerative braking.

Chassis Set Up.

Before testing, Persport 3574 was driven to qualitatively determine the best toe in setting and tire pressures. Toe in was set at 1/4 inch with a 130 lb person. This setting seemed to provide the proper amount of steering stability. Tire pressures chosen were 36 psi for the front tires and 39 psi for the rear tires. This combination of pressures seemed to provide the most neutral handling at the highest pressures to reduce rolling resistance and still maintain proper grip.

City-el 4133 and 4144 were both tested with the same tire pressures used in the rest of the City-el program. Front tires were inflated to 35 psi and rear tires to 40 psi. After testing was finished, a bent left wheel was found on City-el 4133. The effect of this on the test results is unknown. However, given the other variables in the test, this is probably insignificant.

All testing on all vehicles was done with the convertible top on and the side curtains rolled up. The charger transformer was left in the vehicle for all testing as well. In order to obtain the highest speeds possible to facilitate the performance testing, both Persport 3574 and City-el 4133 were run with the motor in the series wound mode rather than with the speed kit installed.

Roll Down Tests.

Once the chassis set up had been determined, roll down tests were performed on Persport 3574 to determine the coefficient of drag times the frontal area (CdA) and the rolling resistance (Croll). For the City-els, the CdA and rolling resistance values were taken from the April 12, 1994 report Rolling Resistance and Coefficient of Drag Testing on the City-el Electric Vehicle.

Testing for the Persport was performed at McClellan AFB on the road indicated on the map included in the appendix. The actual coast down section was just south of building 411. The method used for the test is described in the Third Edition of the Bosch Automotive Handbook on page 325. Initial tests were performed just as described. Later tests though used the DAS to record the speed and the time rather than a stop watch and a frequency readout. During early testing, the frequency readout was connected to the speed sensor and used to determine the vehicle speed more accurately. During later testing, coast down sections of the DAS file were marked with the DAS marking device. This device was used throughout testing and changes the DAS temperature to 146 degrees Celsius. This allows any part of the DAS file from 2 seconds to the whole file to be marked for later review. The test road had less than 0.5% grade according to a 2 foot contour map of the base. Roll down tests were performed in both directions to reduce the amount of error due to the grade and any prevailing winds. High speed runs from 30 mi/hr to 25 mi/hr were done for the first 2/3rds of the battery capacity. The final third of the battery capacity was used to do low speed runs from 15 mi/hr to 10 mi/hr.

The data from both the manual runs and the DAS runs was averaged to produce the CdA and the rolling resistance. Both methods produced similar results. The results from the test on Persport 3574 and the values taken from the April 12, 1994 report for the City-el are listed in the table below.

Coefficients for Aerodynamic Drag and Rolling Resistance

Vehicle	CdA	Croll
Persport 3574	0.66	0.0120
City-el	0.47	0.0136

The slightly lower rolling resistance of the Persport was an unexpected result. It could be that the variation in the road surface between the City-el test and the Persport test is responsible. It could also be that the lighter loading on the front tires has reduced the rolling resistance in spite of the increased number of tires. Testing error is also a very real possibility. At some later date it would be worth testing a City-el on the same section of road as was used for the Persport test.

Road Tests.

In addition to the roll down tests, some on road tests were performed on the McClellan AFB EV Course. These tests were done to compare performance and energy use of the Persport with that of the City-el under real conditions. The data from these tests was also used to compare the actual power use to that predicted by mathematical models using the CdA and Croll for each vehicle.

Course Description.

To facilitate the analysis of the data, the McClellan AFB EV Course was carefully characterized. A map of the base is included in the appendix and shows the EV Course. Each significant feature on the course was denoted by a code. These codes are marked on

the map and a complete list of the codes with a description of the features they represent is included in the appendix. Review the map and the McClellan AFB EV Course Description now. The feature codes are used in the remainder of the report. Unusual events like particularly slow trucks or passing were also recorded for later use in evaluating the data.

The distance to each feature was found using the DAS data. The DAS marking device was used to place a mark in the DAS file for each feature. Later, the cumulative distance was found by adding the speed in meters/second for each second of the DAS file. The distance corresponding to each feature mark was then recorded. Data from several files was averaged to give the final distances listed in the McClellan AFB EV Course Description. Accuracy for these distances is about plus or minus 5 meters. It should be remembered that the distances listed represent the entry to each feature. The difference is typically small, but in turns , the loss of speed through the turn follows the mark for the turn.

A 2 foot contour map of McClellan was used to determine both the location and height of hills and the compass direction of travel for each section of road. The compass travel directions between each feature are listed in the McClellan AFB EV Course Description. In some cases, the direction is an average, and this has been noted where applicable. The grades on the EV Course are generally less than 0.5%. There are some short grades that are greater than this, but they do not show up clearly on the 2 foot contours. As a result, the course has been considered to be flat other than some comments in the feature descriptions which note some of the more obvious short grades.

A brief summary of weather conditions during the road tests was also obtained from the McClellan weather station. A copy of this sheet is included in the appendix. In addition to the usual temperature and precipitation information, it lists the compass direction of the wind and the peak wind speed for each day.

Notes on the Data.

Data for the on road test was obtained using the City-el DAS. In order to avoid errors with the DAS calibration of the main shunt, each vehicle had a calibration check done. This calibration check was done by driving the vehicle with both the computer hooked to the DAS and a multimeter hooked to the main shunt. At various current values, the reading on the multimeter and the DAS were recorded. These values were then plotted and a least squares fit line was created. The equation of this line was used to create an adjustment equation that corrected the DAS current values for errors in the calibration. In the case of City-el 4144 with regen, two adjustment equations were created. One was for zero to positive values, and the other was for zero to negative values. All three vehicles used in these tests showed a 10 to 20 amp error at the maximum 120 amp current when checked in this manner. Previous tests have shown that the voltage, distance, and temperature values reported by the DAS are fairly accurate so a check of these values was not done.

In order to avoid energy use and distance errors, the beginning and end of each test was carefully controlled. The vehicle was rolled to the starting point behind building 335. Once in position, the computer was set to take second by second data and the vehicle was

turned on. From this point, the test run began. At the end of the test, the vehicle was stopped on the same mark it started from. Then vehicle was turned off and the computer was shut down. The vehicle was then rolled out of the road. In the case of sequential runs, the vehicle was stopped on the starting mark and a long pause was taken before starting the next run. Using this method and the DAS marking device, the beginning and end of each run could be easily found.

DAS files were named using the standard DAS naming convention. These files were later imported to a spreadsheet and each individual run was separated to a separate spreadsheet and expanded to 1485 seconds. The last row of data was copied in order to expand the file. Each spreadsheet was then named using a slight variation on the DAS naming convention. The leading "D" was dropped and an "A", "B", or "C" was added after the Julian date in order to denote whether it was the first, second, or third run for the day. The extension was changed to the usual spreadsheet extension. These files were then linked to another spreadsheet that functioned as the graphing and analysis engine for the data. A complete list of the files used for this report is included in the appendix.

Energy Use Comparison.

Once the data was linked to the graphing and analysis spreadsheet the energy use for each trip around the base could be determined. After adjusting the DAS current reading with the adjustment equation created after the calibration check, the current was multiplied by the voltage to give the second by second power use of the vehicle. This was then summed and divided by 3600 to give the number of Watt-hours used for each trip around the base. The total per trip energy use for each vehicle was then averaged and divided by the course distance of 8.92 miles to give the average energy use per mile. These values are shown in the Energy Use Comparison Driving Around McClellan AFB EV Course graph included in the appendix. The graph shows that Persport 3574 used 18% more energy per mile than City-el 4133. City-el 4144 with regen posted an improvement of about 5% over City-el 4133. Although it has not been included here, the data indicates that driving style differences may change energy use by as much as 14%.

Performance Comparison.

Graphs of speed and acceleration plotted versus the course distance were compared to evaluate differences in handling and performance. In order to make these comparisons, both Persport 3574 and City-el 4133 were driven to the limit of their performance. Keep in mind that slight differences in driver performance and conditions still exist in the data. The best and most uninterrupted run for each vehicle is included in the appendix. See Persport 3574. 5-12-95. 5745132A.XLS, Speed Graph and City-el 4133. 5-12-95. 1335132A.XLS, Speed Graph included in the appendix.

A careful review of the graphs will show that the Persport is capable of as much as 4.5 mi/hr higher speeds around the corners. This is particularly evident for turns T4, T5, T6, T17, T18, and T19. In some of the other turns the Persport is slower than the City-el, but this has more to do with the top speed of the vehicle at the time than the handling performance. The two turns with the most difference are turns T17 and T19. Both of these turns are banked out, a condition which exposes the City-el's handling problems.

Although the quantitative differences between the vehicles performance are fairly small, the qualitative differences are significant. A fairly inexperienced driver can comfortably take the Persport all the way to the handling limit. Under dry conditions the onset of oversteer is fairly predictable, and should the vehicle spin, a trip onto the shoulder or into the ditch is the worst that will happen. The City-el, however, requires a significant amount of driver experience and control. It is necessary for the driver to shift his weight as low and as far to the inside of the corner as possible including leaning out the window. Under these conditions, the City-el also goes into slight oversteer but borders dangerously on the edge of rolling over. Any slight hole or ripple in the pavement could easily upset the balance and send the vehicle rolling into the ditch.

The City-el does have a couple of areas where it is superior to the Persport. Straight line stability and on center feel are much better in the City-el than in the Persport. The turning rate of the City-el is also better suited to the size and operating environment of the vehicle. Given that the Persport employs a prototype suspension this kind of problem is not surprising, and could probably be remedied with further development.

Acceleration differences were not noticeable. A graph of acceleration that corresponds to the Persport speed graph mentioned above is included in the appendix. See Persport 3574. 5-12-95. 5745132A.XLS. Accel Graph.

Power Comparison.

Because of the differences in speed and acceleration between vehicles and from trip to trip, it is difficult to compare the power differences from vehicle to vehicle. For this reason, mathematical models of the power use for each vehicle were developed. These models were then checked against the actual power to evaluate the validity of the model. The following discussion refers to the following two graphs which are included in the appendix: Persport 3574. 5-12-95. 5745132A.XLS. Power Compare Graph and City-el 4144 with Regen. 5-26-95. 1445146A.XLS. Power Compare Graph. Note that the Persport power graph corresponds to the Persport speed and acceleration graphs mentioned earlier in this report.

Several things should be noted about the actual power plots on these two graphs. First, Persport 3574 was driven very hard during this run as part of the performance testing. City-el 4144 on the other hand was not driven so hard. Second, when driving City-el 4144, it was necessary to follow a very slow truck which eventually stopped in the middle of the road between SR2 and T1. This is the reason there is such a difference in the power use over this distance. Finally, the regenerative braking system on City-el 4144 was an experimental system that lacked good modulation. Because of this, regen events tend to be sharp spikes or sets of sharp spikes.

The theoretical battery power equations developed for each vehicle are shown below. The table below summarizes the values used for various variables. Descriptions and notes on these equations follow.

Power Equations:

$$Power = \frac{Mech.Power}{PowertrainEff.}$$

$$Regen.Power = Mech.Power \cdot PowertrainEff.$$

$$PowertrainEff. = -0.0074\upsilon^2 + 0.1476\upsilon + 0.0747$$

$$Mech.Power = m\upsilon \cdot \mathrm{Sin}(\mathrm{Atan}(\%g)) + mC_{roll}\upsilon \cdot \mathrm{Cos}(\mathrm{Atan}(\%g)) + \tfrac{1}{2}CdA\rho\upsilon \cdot (\upsilon + \upsilon_w)^2 + ma\upsilon$$

$$\upsilon_w = Vwind \cdot \mathrm{Cos}(\tfrac{\pi}{180} \cdot (trvl.dir. - wind.dir.))$$

Variable Descriptions:

m = Vehicle mass (kg)

υ = Vehicle speed ($^m/_s$)

a = Vehicle acceleration ($^m/_{s^2}$)

C_{roll} = Coefficient of rolling resistance

CdA = Coefficient of drag and frontal area (m^2)

ρ = Air density ($^{kg}/_{m^3}$)

$\%g$ = Percent grade

υ_w = Wind speed on vehicle ($^m/_s$)

$Vwind$ = Average wind speed ($^m/_s$)

$trvl.dir.$ = Vehicle travel direction (degrees)

$wind.dir.$ = Wind direction (degrees)

Values Used for Variables.

Variable	Persport	City-el
m (kg)	402	389
C_{roll}	0.0120	0.0136
CdA (m^2)	0.66	0.47
ρ ($^{kg}/_{m^3}$)	1.202	1.202
$\%g$	0	0
$Vwind$ ($^m/_s$)	4.5	4.5
$wind.dir.$ (deg.)	195°	195°

The power required to move the vehicle (*Mech.Power*) must be divided by the efficiency of the drive train (*PowertrainEff.*) including the motor and controller efficiencies to give the power required from the batteries (*Power*). In the case of a regen event though, the mechanical power is being fed through the drive to the batteries. For this reason, the mechanical power must be multiplied by the drive train efficiency to give the regenerative braking power (*Regen.Power*) that reaches the batteries.

Drive train efficiency is a very complex quantity including bearing losses, belt losses, controller losses, I^2R losses, and motor energy conversion losses. The drive train efficiency equation used for this report is a very simplified version of the complete drive train efficiency. The equation was obtained by fitting a second order polynomial with a least squares fit to the City-el motor curve supplied by City-Com. This curve is supposed to include all or most of the other drive train losses, but this fact has not been verified. It is important to realize that this curve is only valid for the full power condition. Motor efficiency is really a 3D surface equation depending on both motor speed and torque. Fortunately, the City-el and the Persport are commonly driven at full power so the equation fits much of the time. It has been assumed that there is no change in the efficiency equation by operating the drive train in reverse for regen.

The first term in the *Mech.Power* equation computes the power required to move the vehicle up a hill. Vehicle mass is a significant part of this term. The vehicles were not weighed during this test so the mass was estimated using previously known masses of the vehicle and adding the mass of the driver. The Persport weighed 311 kg just after being completed. The weight of City-els 4133 and 4144 were estimated using the mass of City-el 4128 which was determined to be 289 kg. To both of these masses, 91 kg was added to account for driver and equipment mass. For this report, this term is always zero because, as mentioned in the Course Description section, the McClellan course was considered to be flat.

The second term in the *Mech.Power* equation computes the power required to over come the rolling resistance of the vehicle. The coefficient of rolling resistance used here was determined during roll down tests on both vehicles. These values are listed in the table above.

The third term in the *Mech.Power* equation computes the power required to over come aerodynamic drag. A standard value for air density was used in this term. The CdA used was determined during roll down tests of the Persport and the City-el. The values for each are listed in the table above. The wind speed used in this term was an estimate using the available information. The wind speed (v_w) on the vehicle was computed using the vehicle travel direction, wind direction, and the average wind speed. This gave a changing magnitude head wind or tail wind depending on the vehicle travel direction. This is only an approximation since it ignores the cross wind component and possible changes in CdA for side or tail winds. For this report, all tail winds (negative values) were ignored by setting $v_w=0$ when the value of v_w was negative. The wind direction used in this report was an average of the direction of the wind over the 4 test days. The average wind speed used was an estimate based on the peak wind speeds during the 4 test days.

The fourth and final term in the *Mech.Power* equation computes the power required to accelerate the vehicle. This term only considers linear acceleration of the vehicle. The rotary acceleration of the wheels, axles, pulleys, and motor armature are not included. Unfortunately, the resolution of the DAS is not fine enough to produce good results with this term. The minimum acceleration step reported by the DAS is ±0.1 m/s^2. This causes changes in power of about 500 Watts. There also seems to be some instability in

this reading as well since it rarely stays at zero. A careful study of the Persport 3574. 5-12-95. 5745132A.XLS. Accel Graph and the Persport 3574. 5-12-95. 5745132A.XLS. Power Compare Graph will show that the noise on the power graph is due to the acceleration values.

Considering the number of approximations, estimated values, and data problems, this power equation does a fairly good job of predicting the power use of either vehicle. There are a few conditions though where it does not do a particularly good job of estimating power use. Under cross wind conditions like exist between T6 to T7, SL3 to SR3, and L3 to nearly mph, it consistently predicts values that are too low. This may indicate that cross winds produce a significant amount of drag. Under hard acceleration it predicts low values as well. This is not surprising given the DAS resolution and that the model does not include rotational acceleration. The same applies to errors during regen events. The section from T7 to SL3 is probably the best fitting area because most of this section is run at constant speed with a direct head wind. There are some small errors through this section, but most can be attributed to small grades that were not included in the course description.

APPENDIX

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Complete List of Backup Data Available on Request	1 page
McClellan AFB EV Course Description	1 page
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Record of Climatological Observations for May	1 page
Energy Use Comparison Driving Around McClellan AFB EV Course	Chart
Persport 3574. 5-12-95. 5745132A.XLS, Speed Graph	2 page Graph
City-el 4133. 5-12-95. 1335132A.XLS, Speed Graph	2 page Graph
Persport 3574. 5-12-95. 5745132A.XLS, Accel Graph	2 page Graph
Persport 3574. 5-12-95. 5745132A.XLS, Power Compare Graph	2 page Graph
City-el 4144 with Regen. 5-12-95. 1445146A.XLS, Power Compare Graph	2 page Graph

Complete List of Back-up Data

Available on Request

Document Title:		**Size:**

Documents: 72KB

MCCOURSE.DOC	List of Course Features and Distances.
PERSPORT.DOC	Final Report (This document)

DAS Files: 1.3MB

D1335130.1SD	D1335130.2SD	D1335131.1SD
D1335132.1SD	D1445146.1SD	D5745110.2SD
D5745130.1SD	D5745130.2SD	D5745131.1SD
D5745132.1SD	D1335130.1TR	D1335130.2TR
D1335131.1TR	D1335132.1TR	D1445146.1TR
D5475110.1T4	D5745130.1TR	D5745131.1TR
D5745131.2TR	D5745132.1TR	D5745158.1TR
D5745159.1TR		

Spreadsheets: 6.7MB

PERSPORT.XLS	General Test Info and Calibration Curves.	
ROLLDOWN.XLS	Contains Roll Down Data and Calculations for CdA.	
GRAPH.XLS	Graphing Engine for Data Spreadsheets.	
1335130A.XLS	1335130B.XLS	1335131A.XLS
1335131B.XLS	1335132A.XLS	1335132B.XLS
1445146A.XLS	1445146B.XLS	1445146C.XLS
5745110A.XLS	5745130A.XLS	5745130B.XLS
5745131A.XLS	5745131B.XLS	5745132A.XLS
5745132B.XLS		

Related Documents: 2.4MB

P&CCOMPR.DOC	Memo Describing COMPARE.XLS
COMPARE.XLS	Preliminary Comparisons of Persport and City-el.
D5745110.XLS	Data Spreadsheet.

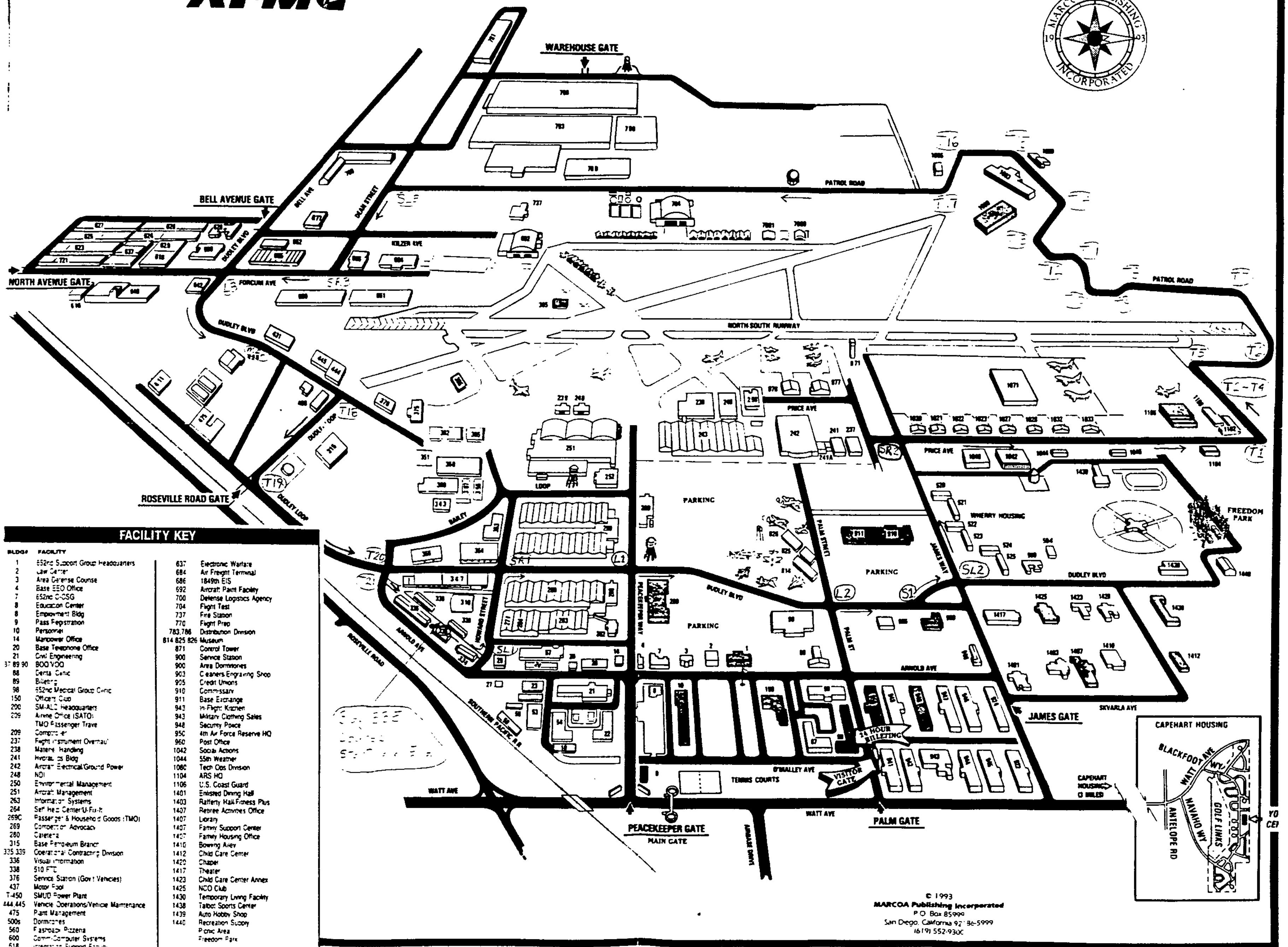
McClellan AFB EV Course Description

Feature	Distance*	Direction	Description
Bldg 335	0	35°	Start at blue writting on pipe patched pavement behind building 335.
SL1	105	270°	Stop and Left turn onto Howard Street.
SR1	312	0°	Stop and Right turn onto Dudley Blvd.
L1	610	15°	Stop light at intersection of Peacekeeper Way.
L2	1139	0°	Stop light at intersection of Palm Street.
S1	1406	336°	Stop sign.
SL2	1511	270°	Stop and Left turn onto James Way.
SR2	1962	0°	Stop and Right turn onto Price Ave.
T1	3043	270°	Left turn 90 deg. Road turns into Patrol Road.
T2	3156	229° avg.	Right turn.
T3	3215	229° avg.	Right turn.
T4	3258	270°	Left turn.
T5	3460	0°	Right turn 90 deg turns onto long straight headed to end of runway.
T6	4341	282°	Left turn 90 deg turns and runs across end of runway.
T7	4896	180°	Left turn 90 deg turns onto longest straight.
T8	6418	151°	Left turn.
T9	6480	180°	Right turn.
T10	6693	223° avg.	Right turn.
T11	6872	223° avg.	Left turn runs underneath the tower.
T12	7052	270°	Right turn frequently has water puddled on right shoulder.
T13	7364	317°	Right turn wide and sweeping.
T14	7814	275°	Left turn wide and sweeping.
T15	8134	175°	Left turn sweeping heads slightly uphill.
T16	8567	62°	Left turn that crests the hill.
T17	8764	180°	Hard Right turn downhill.
H1	9092	180°	Hill Crest
H2	9340	180°	Hill Crest
H3	9868	180°	Hill Crest has a gradual Left-Right turn.
SL3	10787	90°	Stop and Left turn onto Dean Street.
SR3	11601	180°	Stop and Right turn onto Forcum Ave.
L3	11994	80° avg.	Stop light and Left turn onto Dudley Blvd.
mph	12916	40°	25 mph speed limit. Frequently has heavy traffic.
T18	13464	102°	Right turn 90 deg onto Dudley Loop.
T19	13644	34° avg.	Left turn at Roseville Road Gate.
T20	14119	34° avg.	Right turn 90 deg onto Arnold Ave.
T21	14155	35°	Left turn 90 deg onto alley behind Bldg 335. This turn is subject to stops to yield for through traffic.
Bldg 335	14356		End at same location as start.

* Distances are accurate to about +/- 5 meters.

McClellan Air Force Base

AFMC



FACILITY KEY

BLDG#	FACILITY
1	652nd Support Group Headquarters
2	Law Center
3	Area Defense Counse
4	Base EEO Office
7	652nd C-CSG
8	Education Center
8	Employment Bldg
9	Pass Registration
10	Personnel
14	Manpower Office
20	Base Telephone Office
21	Civil Engineering
37 89 90	BOQ/VOQ
88	Dental Clinic
89	Billeting
98	652nd Medical Group Clinic
150	Officers Club
200	SM-ALC Headquarters
209	Airline Office (SATO)
	TMO Passenger Trave
209	Comptroller
237	Flight Instrument Overhaul
238	Materiel Handling
241	Hydraulics Bldg
242	Aircraft Electrical/Ground Power
248	NDI
250	Environmental Management
251	Aircraft Management
263	Information Systems
264	Self Help Center/U-Fix-It
269C	Passenger & Household Goods (TMO)
269	Competition Advocacy
280	Cafeteria
315	Base Petroleum Branch
335 339	Operational Contracting Division
336	Visual Information
338	510 FTC
376	Service Station (Gov't Vehicles)
437	Motor Pool
T-450	SMUD Power Plant
444,445	Vehicle Operations/Vehicle Maintenance
475	Plant Management
500s	Dormitories
560	Flashpoint Pizzeria
600	Comm-Computer Systems
618	Integration Support Facility
637	Electronic Warfare
684	Air Freight Terminal
686	1849th EIS
692	Aircraft Paint Facility
700	Defense Logistics Agency
704	Flight Test
737	Fire Station
770	Flight Prep
783,786	Distribution Division
814 825 826	Museum
871	Control Tower
900	Service Station
900	Area Dormitories
903	Cleaners/Engraving Shop
905	Credit Unions
910	Commissary
911	Base Exchange
943	In-Flight Kitchen
943	Military Clothing Sales
948	Security Police
950	4th Air Force Reserve HQ
960	Post Office
1042	Social Actions
1044	55th Weather
1080	Tech Ops Division
1104	ARS HQ
1106	U.S. Coast Guard
1401	Enlisted Dining Hall
1403	Rafferty Hall/Fitness Plus
1407	Retiree Activities Office
1407	Library
1407	Family Support Center
1407	Family Housing Office
1410	Bowling Alley
1412	Child Care Center
1420	Chapel
1417	Theater
1423	Child Care Center Annex
1425	NCO Club
1430	Temporary Living Facility
1438	Talbot Sports Center
1439	Auto Hobby Shop
1440	Recreation Supply
	Picnic Area
	Freedom Park

STATE OF CALIFORNIA – DEPARTMENT OF WATER RESOURCES

RECORD OF CLIMATOLOGICAL OBSERVATIONS

STATION: MCCLELLAN AFB MONTH: MAY , 1995

Station number: 5447

Seasonal rain totals (since October 1): Begin Month: 34.69 End Month: 37.49

Times of observation: temperature , precipitation

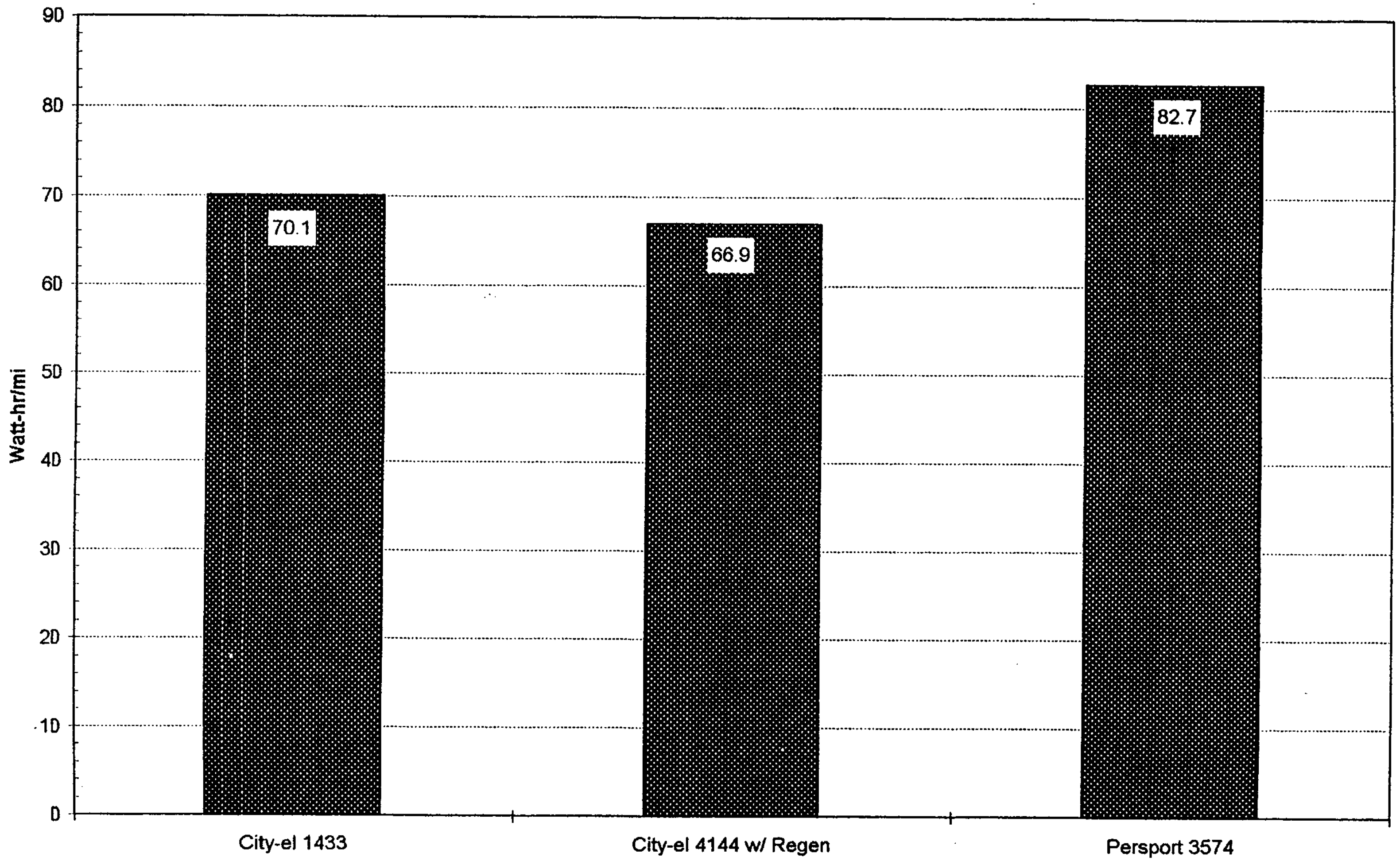
DAY	TEMPERATURE °F MAX	MIN	at obsn.	PRECIPITATION RAIN (X.XX inch)	SNOW (X.X inch)	at obsn. Snow on gnd. (X inch)	WEATHER Fog	Sleet	Glaze	Thunder	Hail	Damaging Wind	Temperature Trend	Important weather conditions, different observation time, comments, remarks, etc. COMPASS / speed (mph)
1	72	58	65	.36	0	0							±0	270/18 CDD: 78
2	73	55	64	0	0	0							-1	300/14 HDD: 77
3	75	53	64	0	0	0							-1	230/11
4	75	54	65	0	0	0							±0	320/17
5	62	46	54	1.73	T	0				X	X		-11	140/18
6	68	46	57	0	0	0							-8	270/10
7	74	55	65	0	0	0							0	230/17
8	72	53	61	0	0	0							-4	220/16
9	64	53	56	.11	0	0							-9	070/12
10	73	49	61	T	0	0							-4	230/13
11	71	54	63	T	0	0							-2	200/19 Peak
12	63	49	56	.27	0	0							-9	170/16 wind speeds
13	63	49	56	.30	0	0							-9	120/19 mph
14	66	54	60	.03	0	0							-5	210/12
15	69	54	62	0	0	0	X						-3	320/13
16	75	49	62	0	0	0							-3	270/14
17	76	55	66	0	0	0							+1	170/13
18	80	54	67	0	0	0							+2	130/11
19	82	58	70	0	0	0							+5	230/11
20	79	51	65	0	0	0							±0	150/17
21	67	50	59	0	0	0							-6	180/20
22	75	51	63	0	0	0							-2	130/15
23	85	55	70	0	0	0							+5	180/14
24	81	55	68	0	0	0							+3	140/19
25	85	54	70	0	0	0							+5	140/14
26	83	54	69	0	0	0							+4	180/15 ← Peak wind speed.
27	85	54	70	0	0	0							+5	120/14
28	92	56	74	0	0	0							+9	360/13
29	95	61	78	0	0	0							+13	280/12
30	92	62	77	0	0	0							+12	210/13
31	92	65	79	0	0	0							+14	330/10
AVG	76	54	TOTALS	2.80	T									

SUPPLIES:
- ☐ forms
- ☐ envelopes
- ☐ other

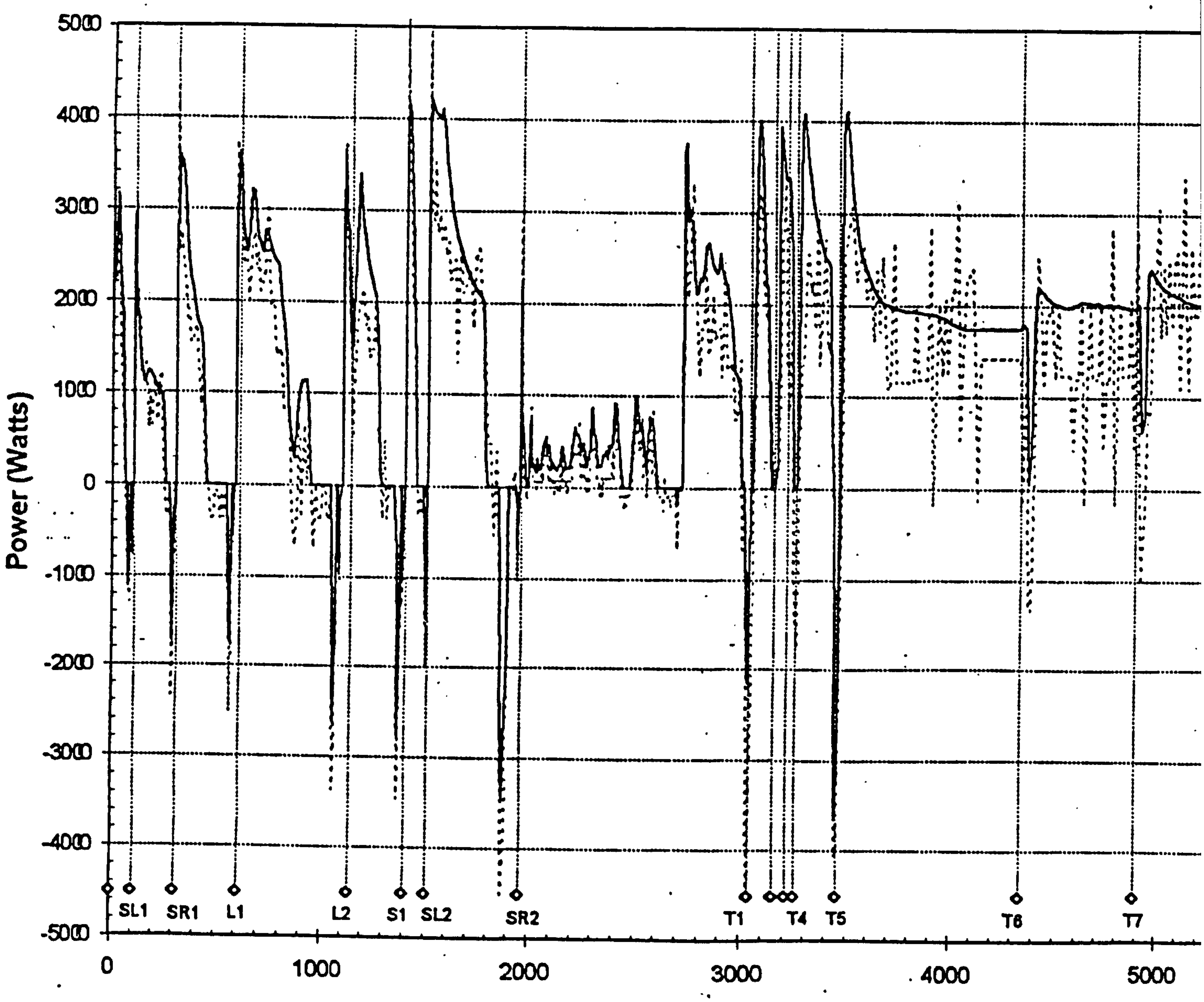
OBSERVER: CRA GODEMANN

ADDRESS: 3029 Peacekeeper Way, Ste 4
McClellan AFB CA 95652

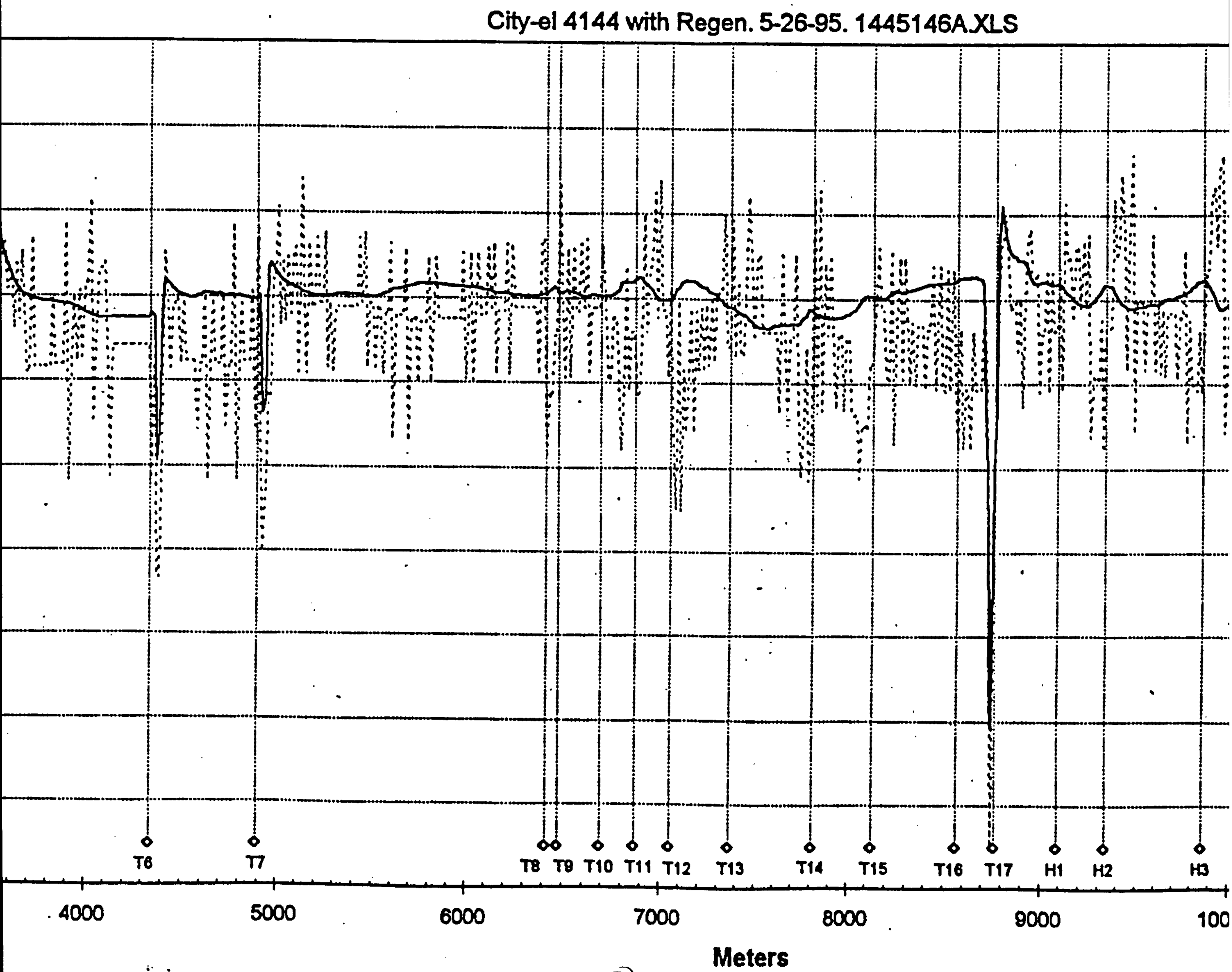
Energy Use Comparison Driving Around McClellan AFB EV Course



McClellan AFB EV Course.

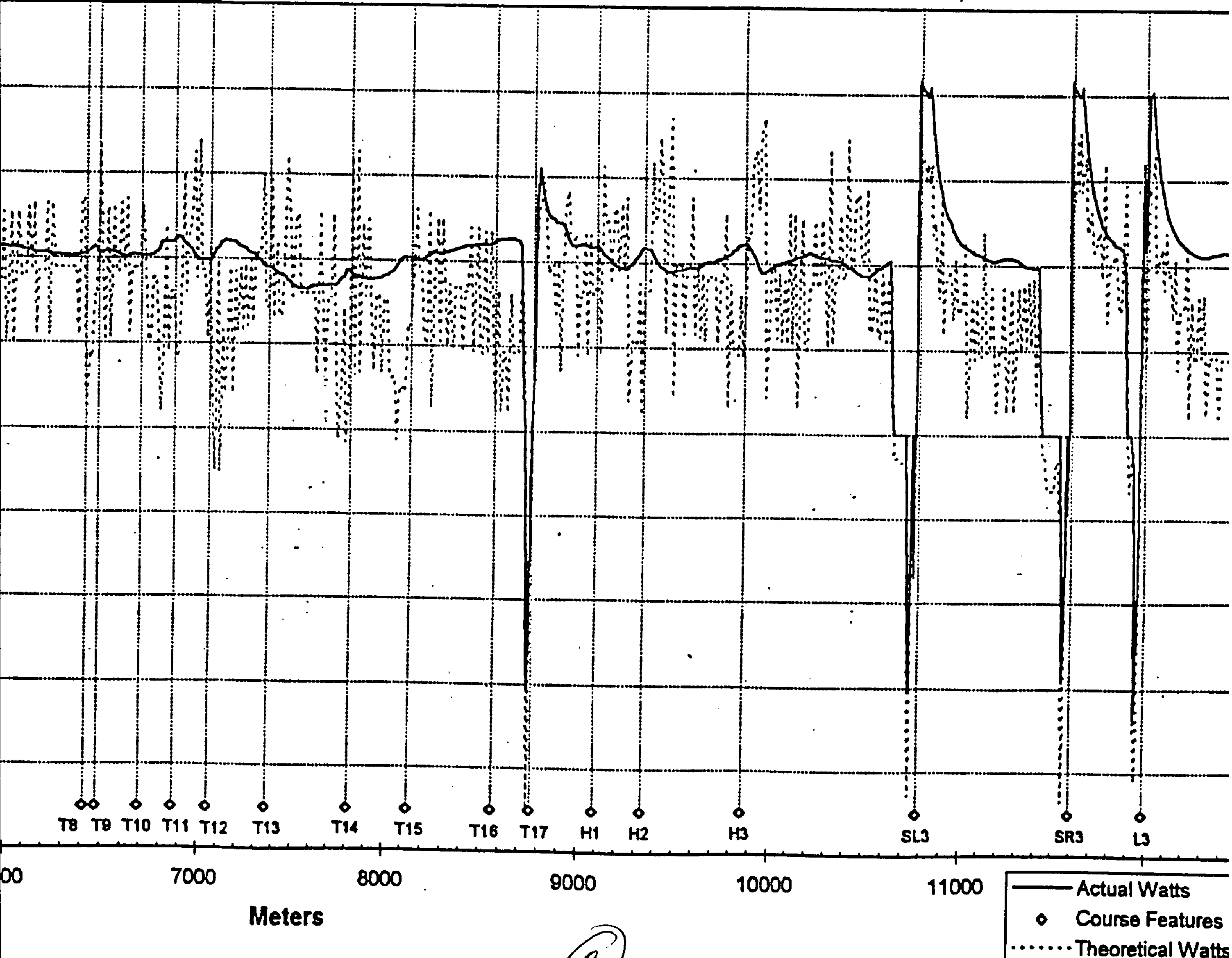


PacificEV: GRAPH.XLS, Power Compare Graph


City-el 4144 with Regen. 5-26-95. 1445146A.XLS
T6
T7
T8
T9
T10
T11
T12
T13
T14
T15
T16
T17
H1
H2
H3
4000
5000
6000
7000
8000
9000
100
Meters

(2)

City-el 4144 with Regen. 5-26-95. 1445146A.XLS



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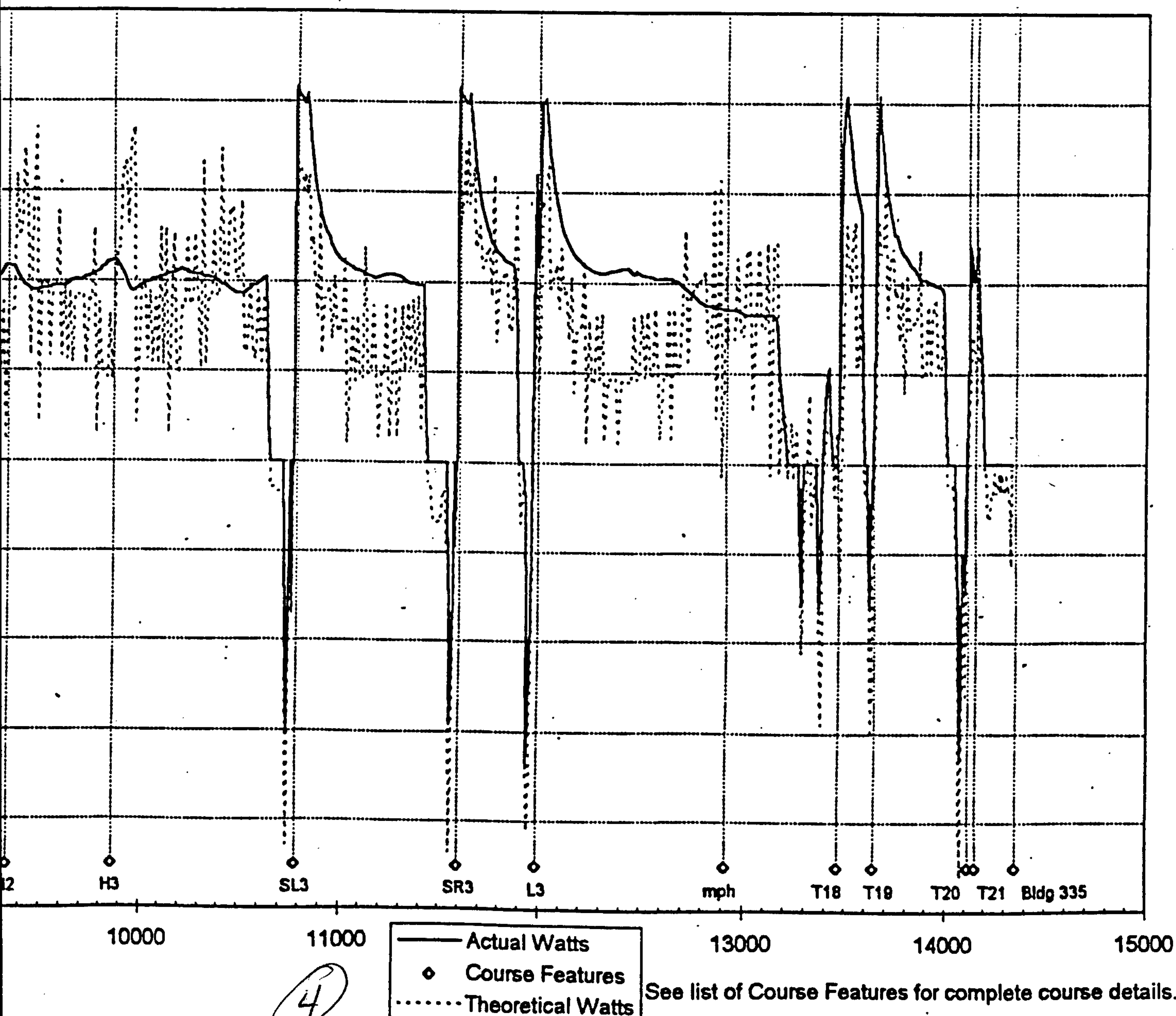
Print Date: 6-21-95



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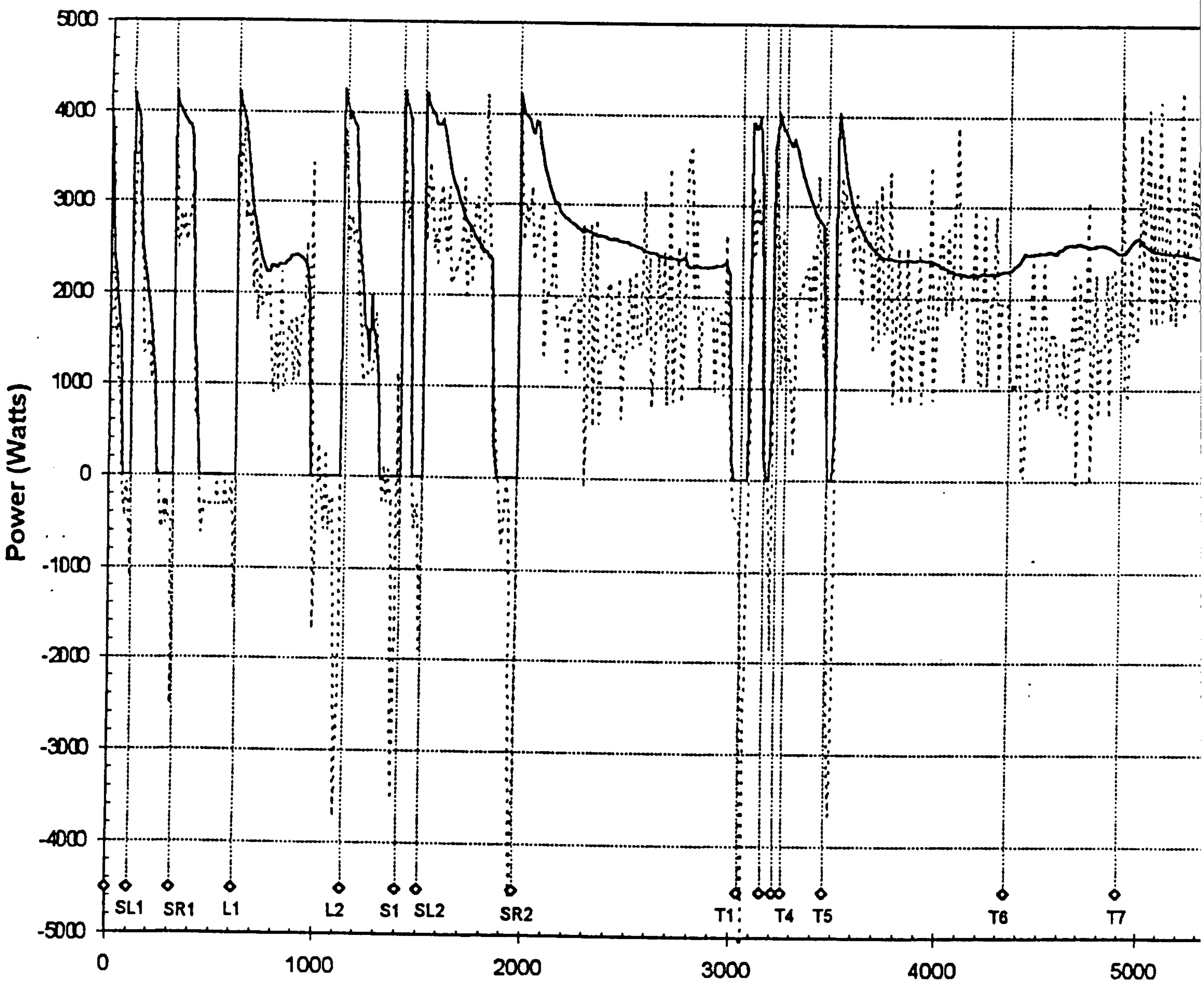
See list of Course Features for complete course details.

McClellan AFB EV Course.



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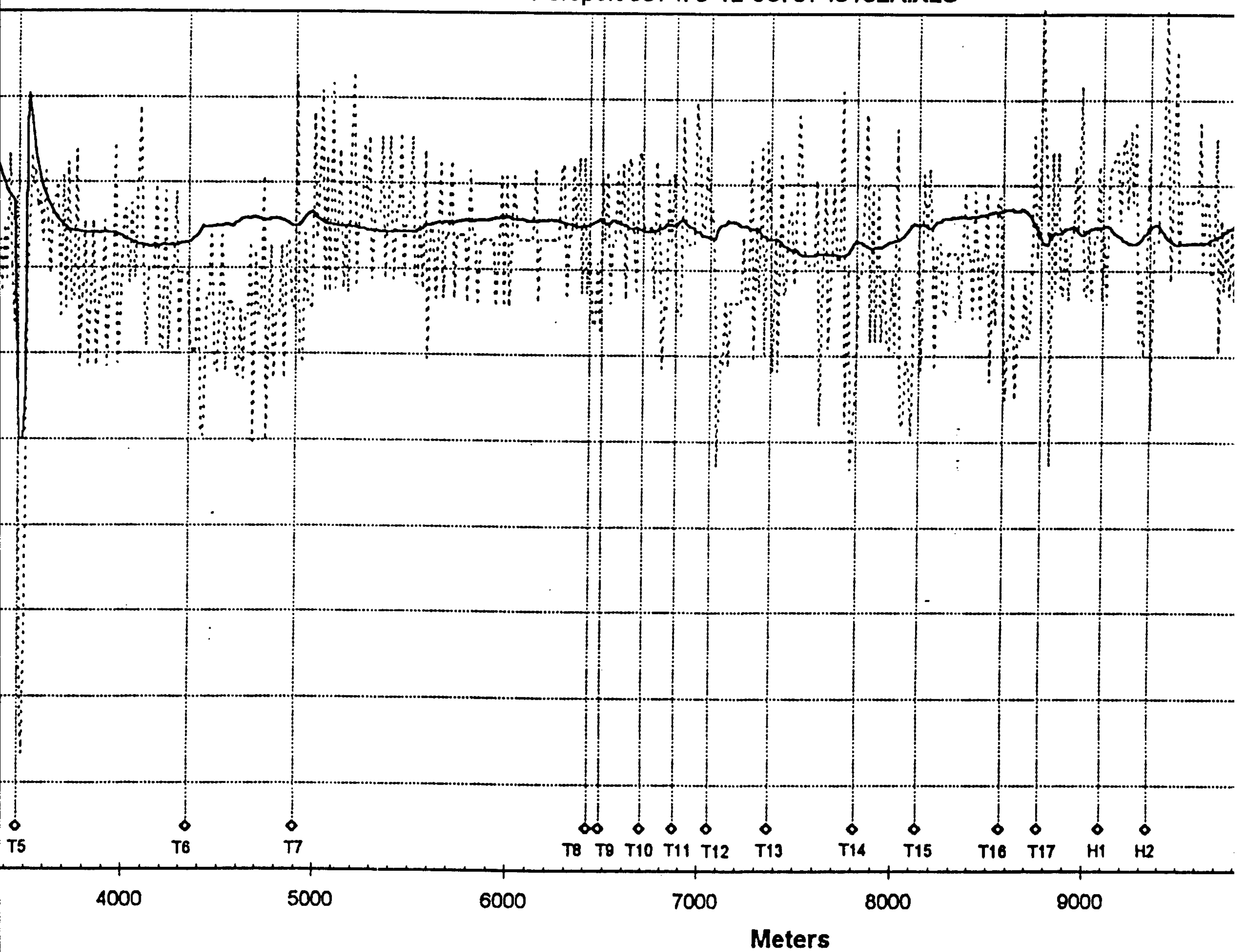
Persport 3574. 5-12-95. 5745132A.XLS



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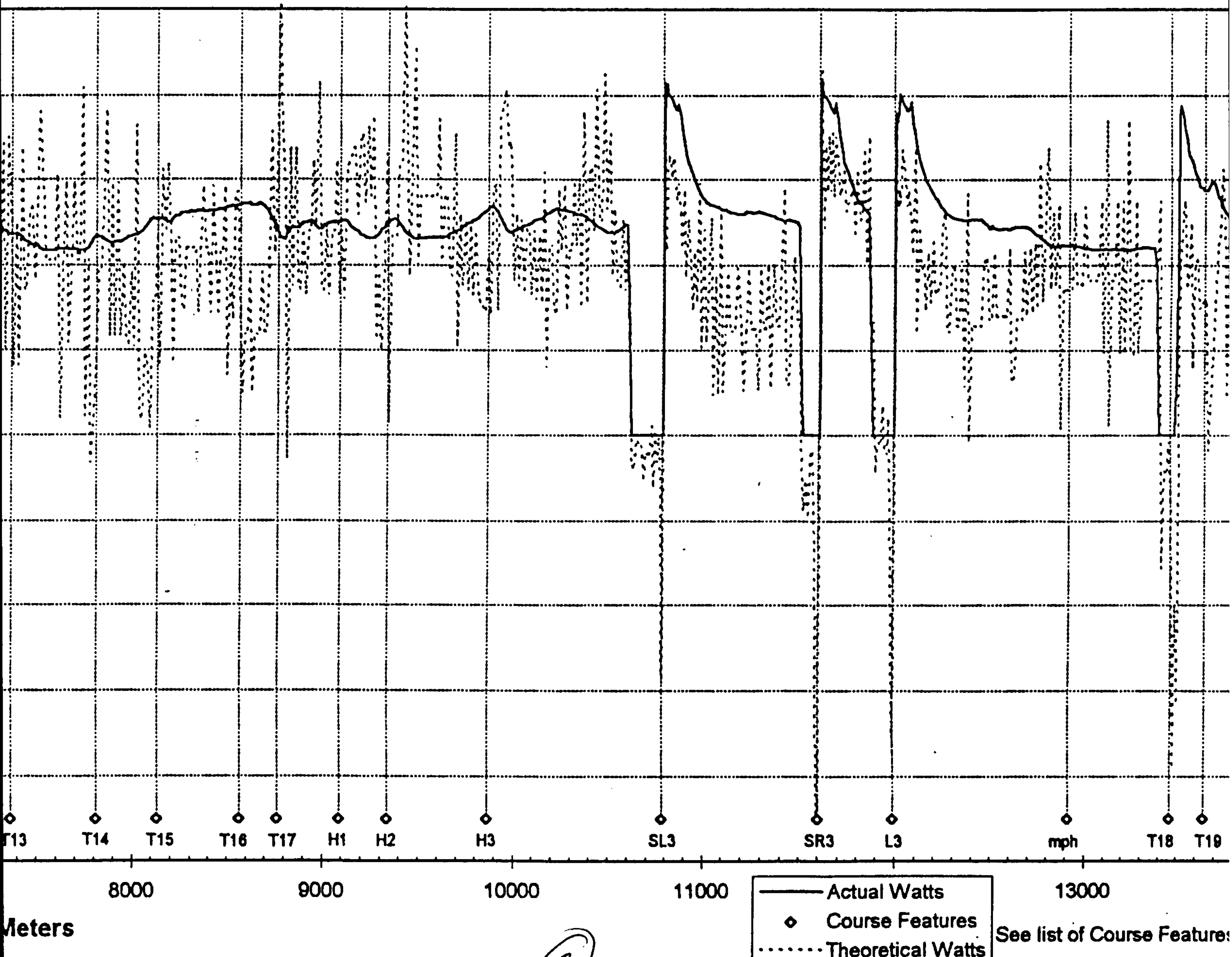
95. 5745132A.XLS



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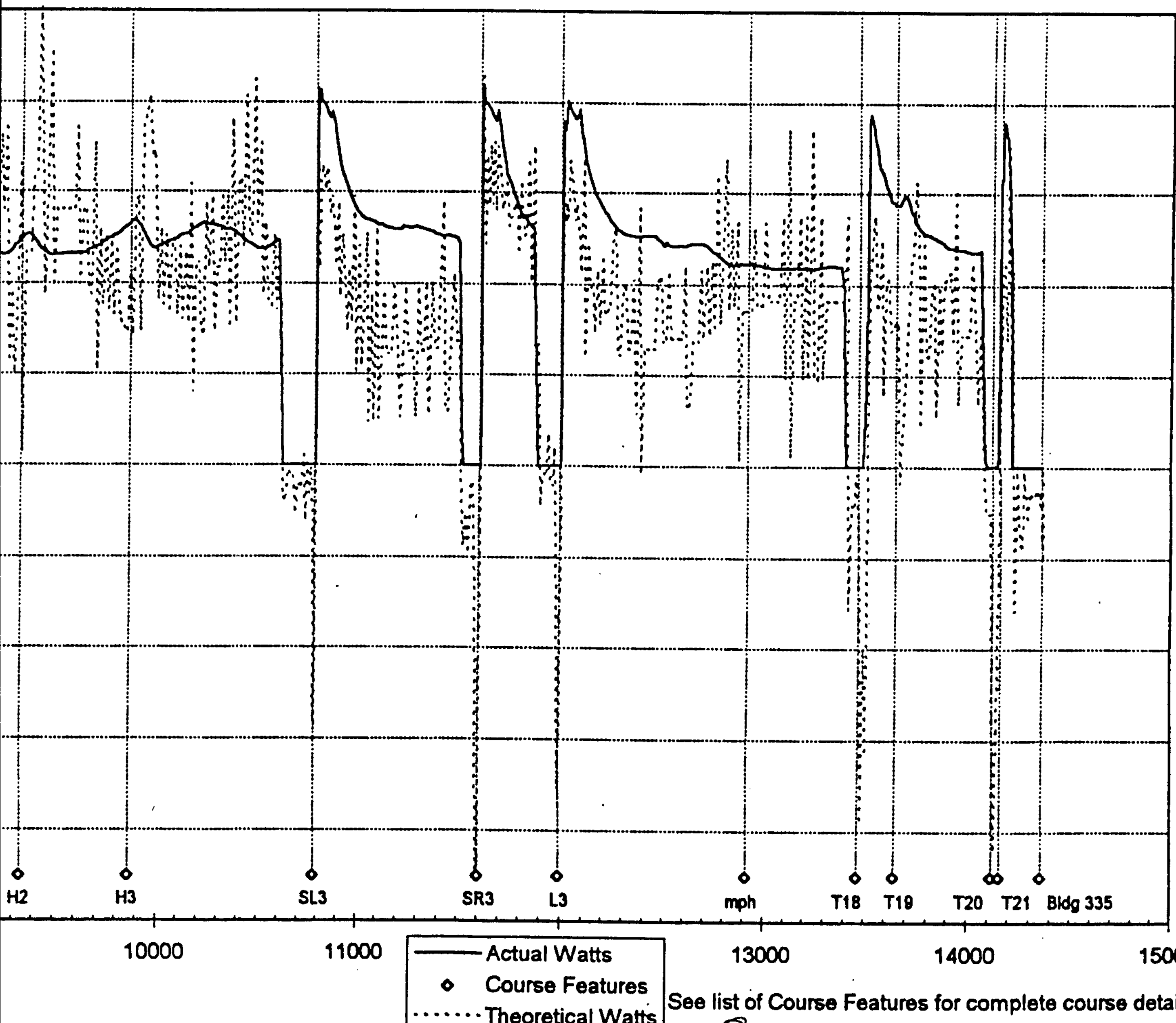

See list of Course Features for complete course details.

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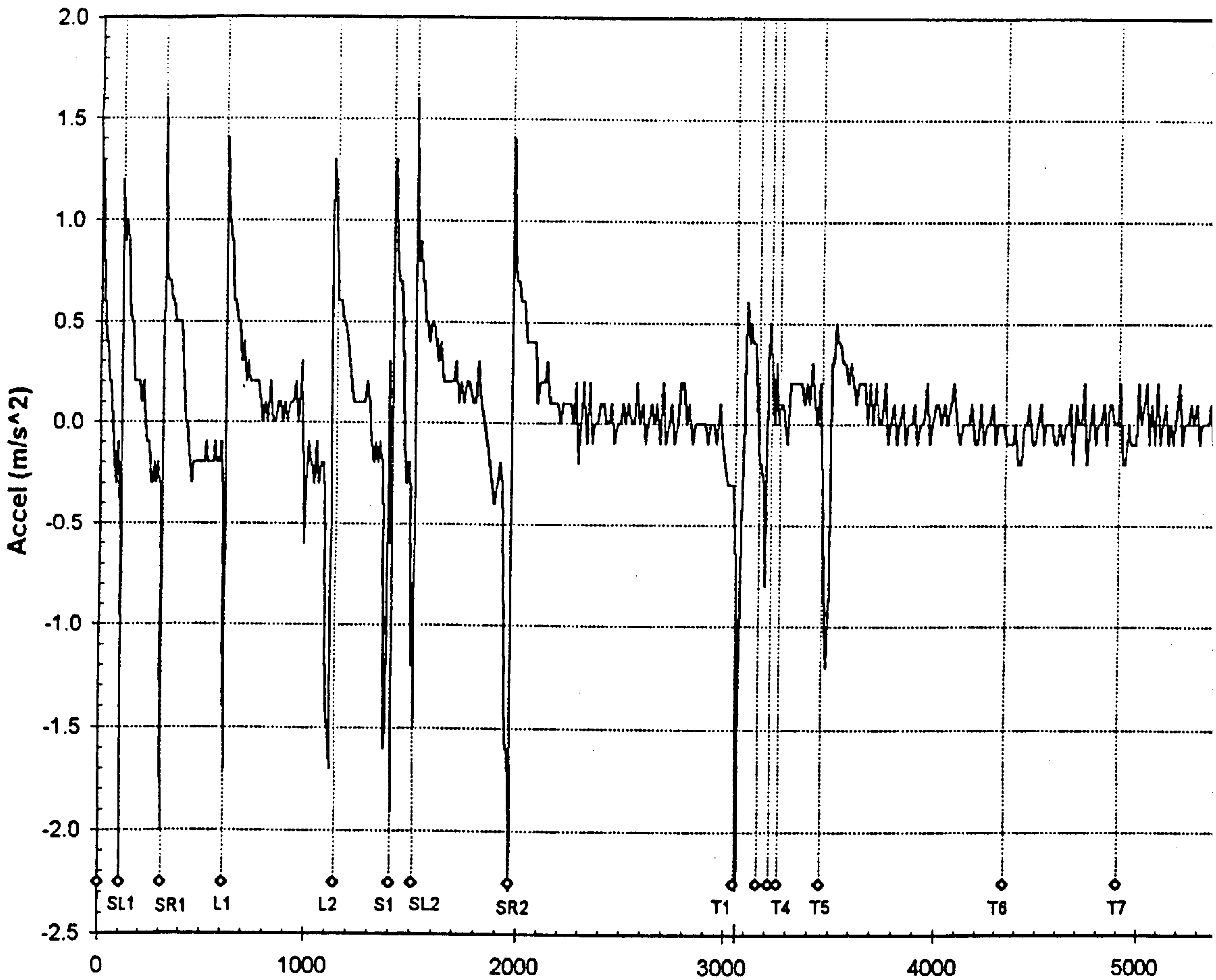
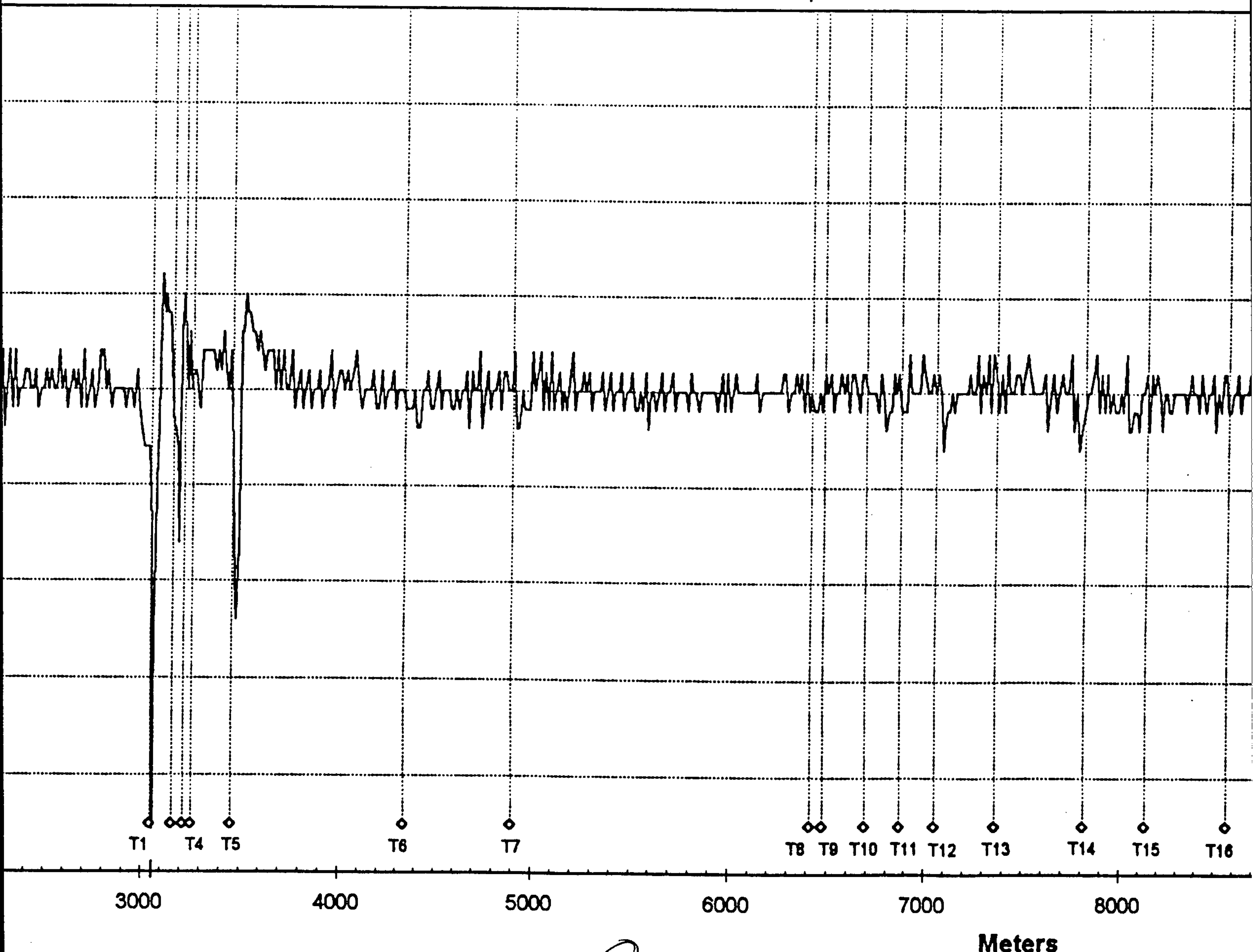
Chart

McClellan AFB EV Course.



Pacific EV: GRAPH.XLS, Accel. Graph

Persport 3574. 5-12-95. 5745132A.XLS



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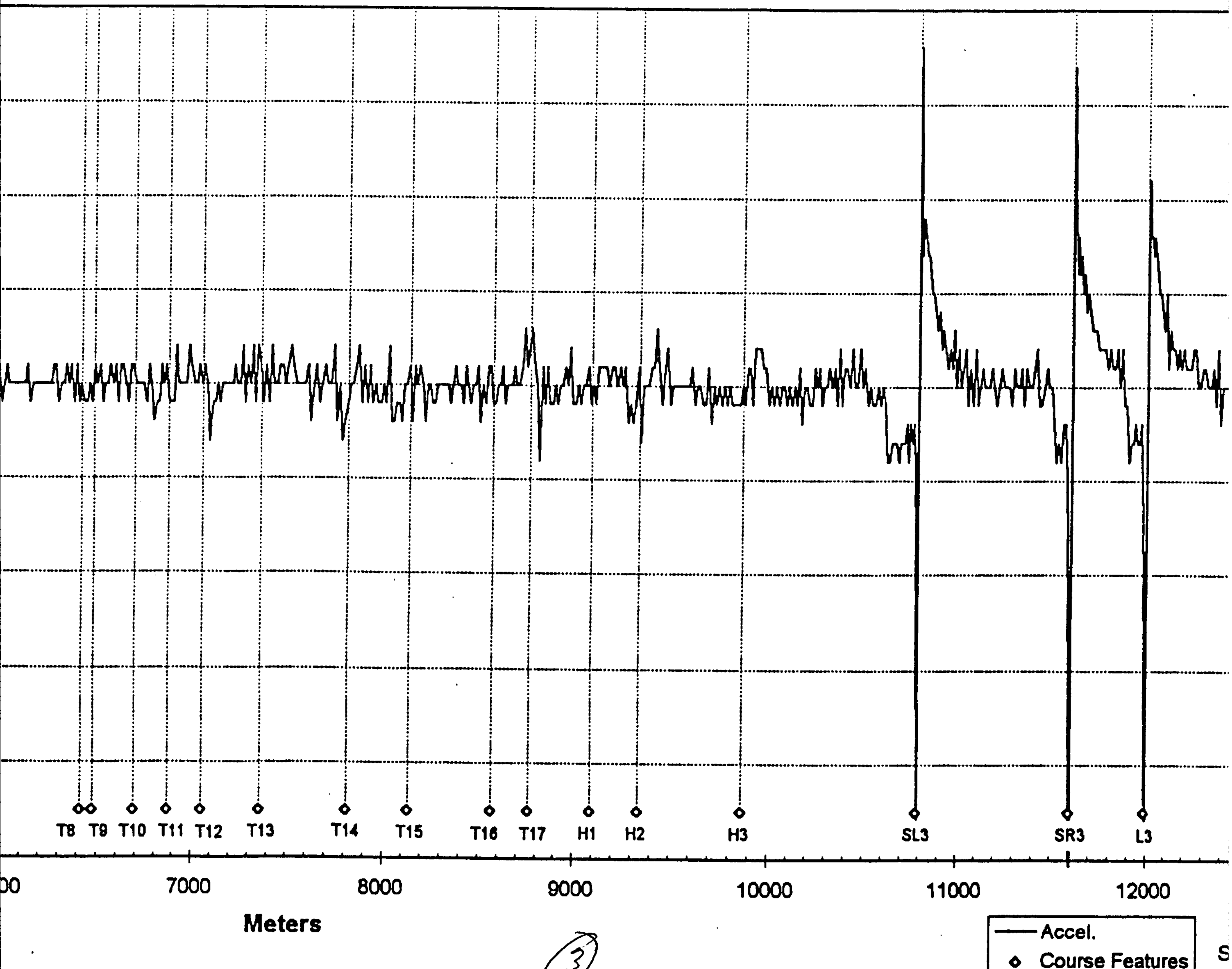

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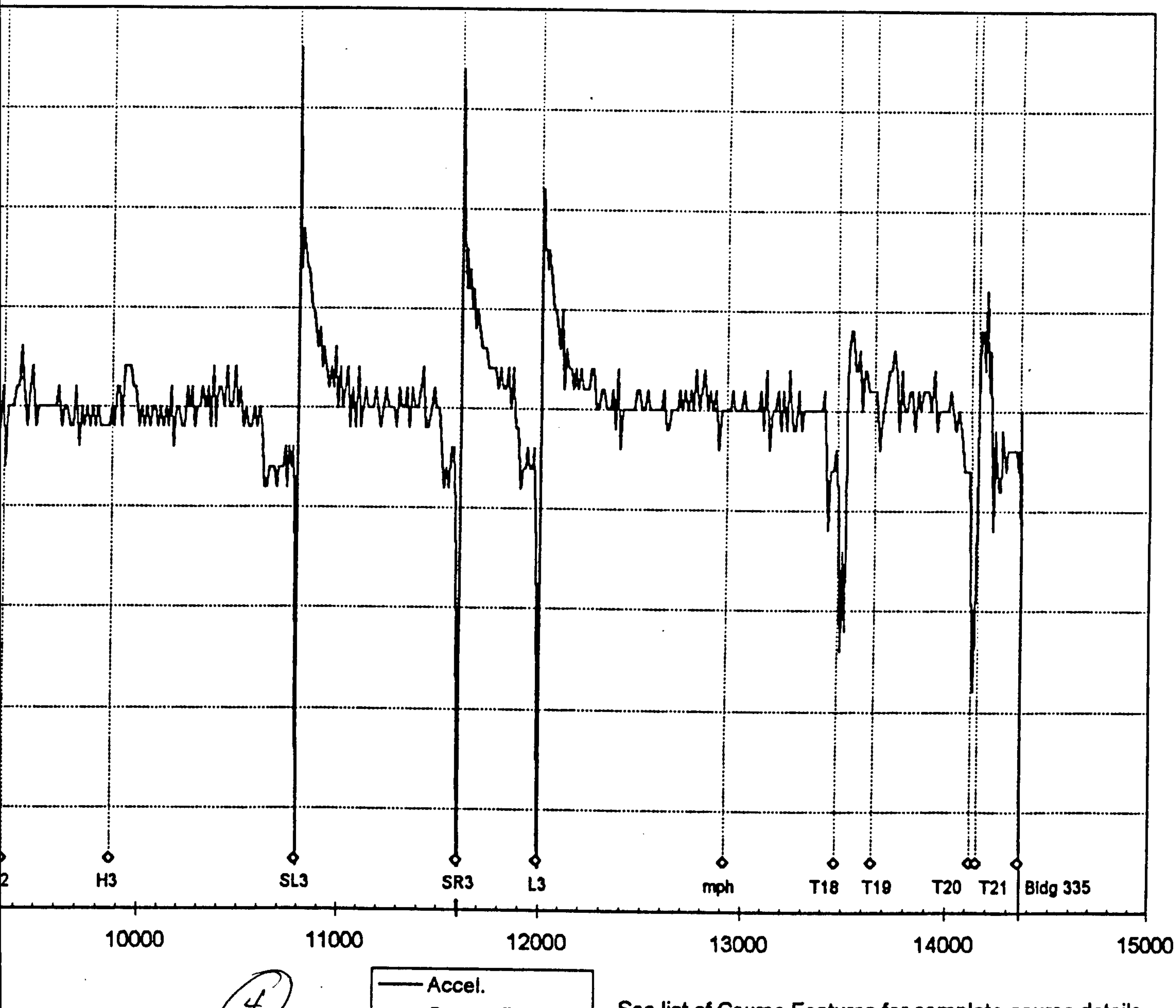

See list of Course Features for complete course details.

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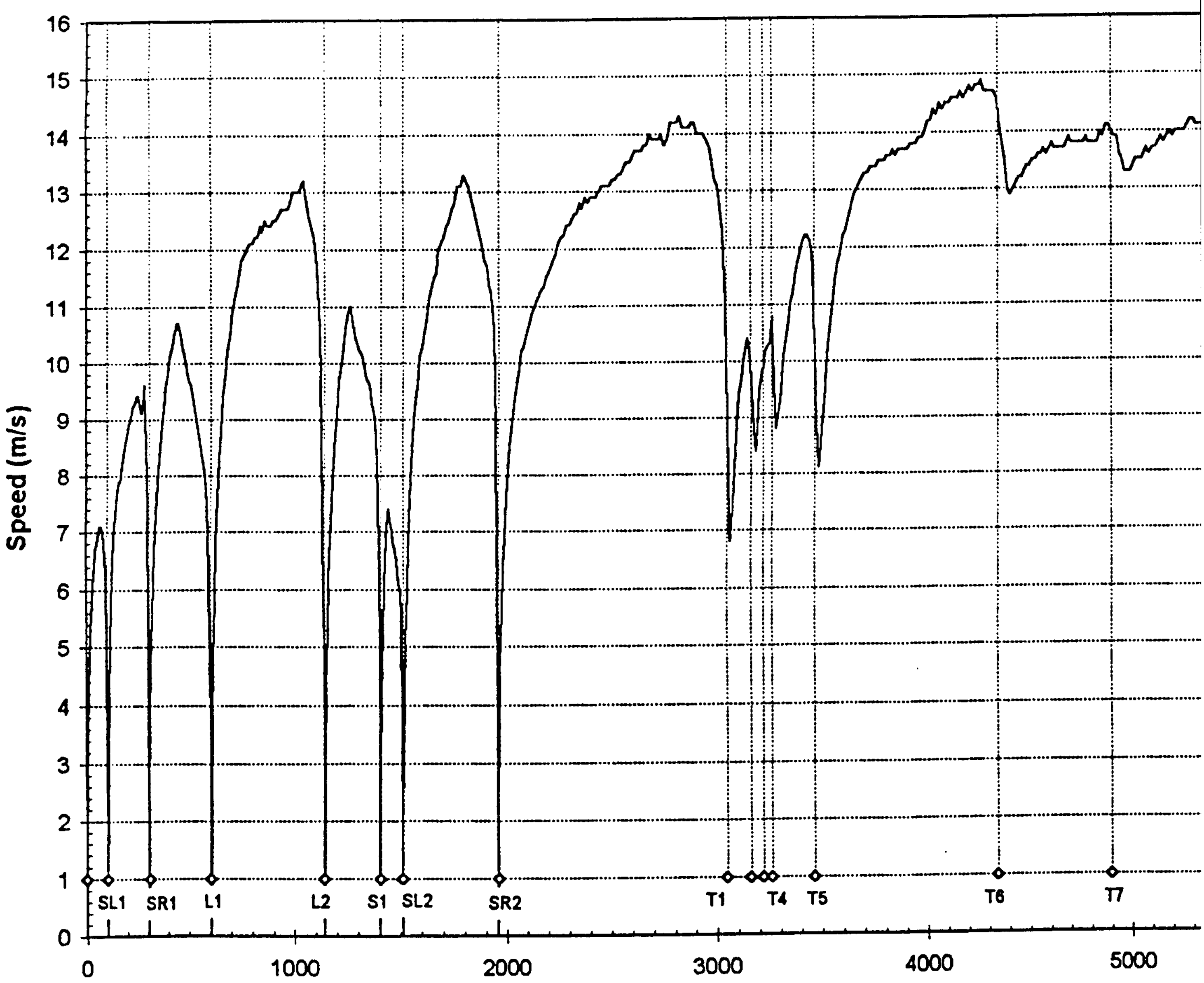
McClellan AFB EV Course.



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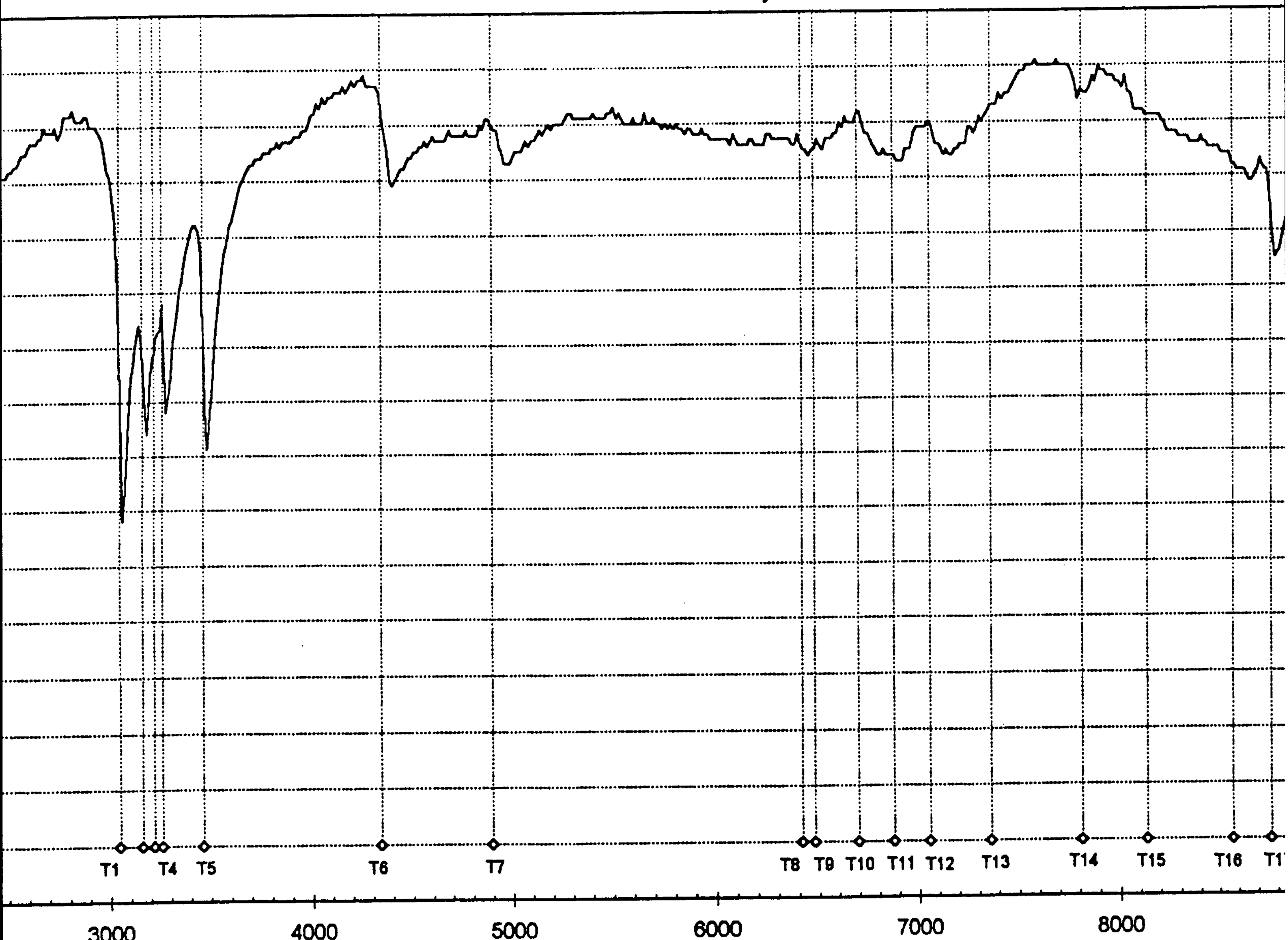

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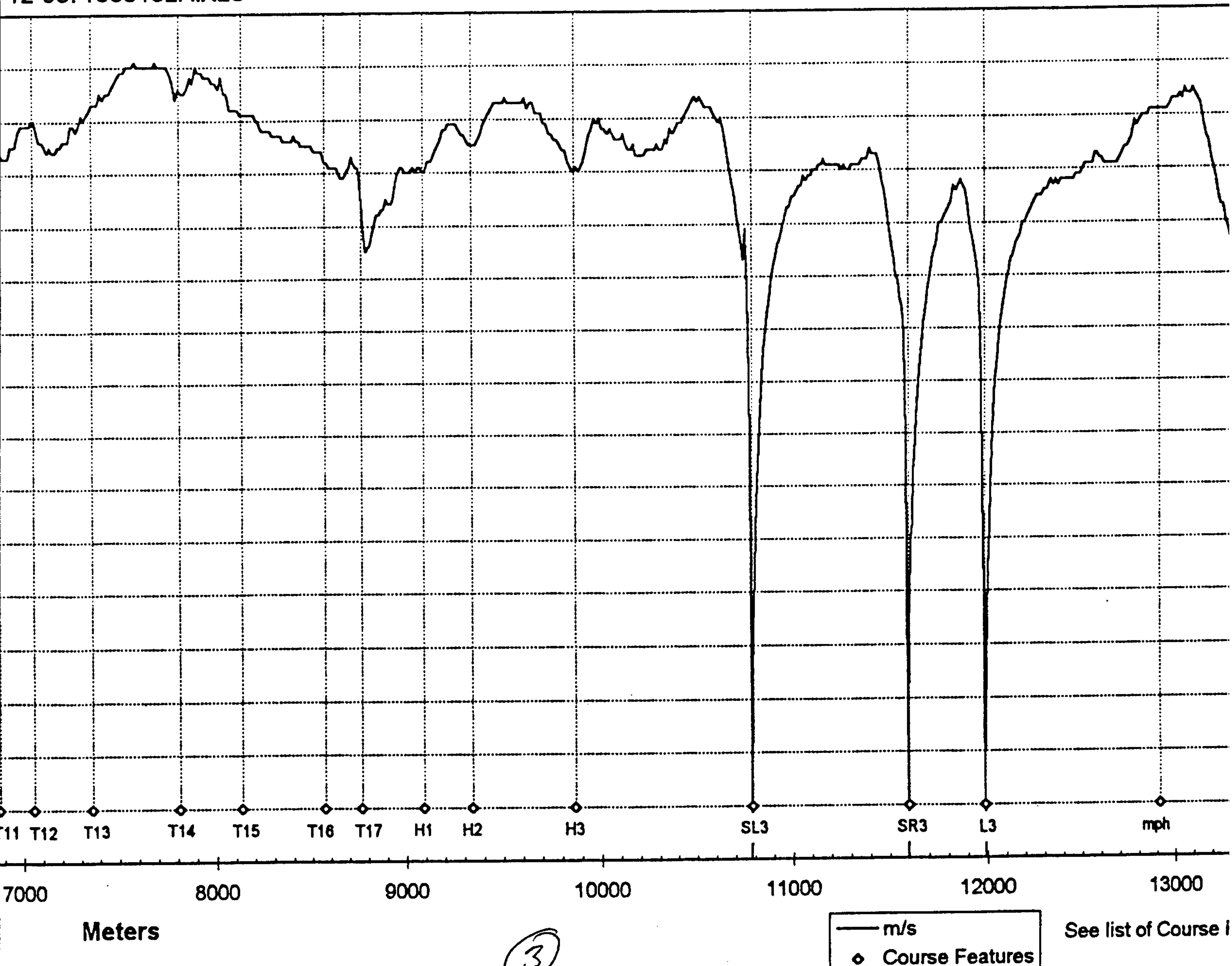

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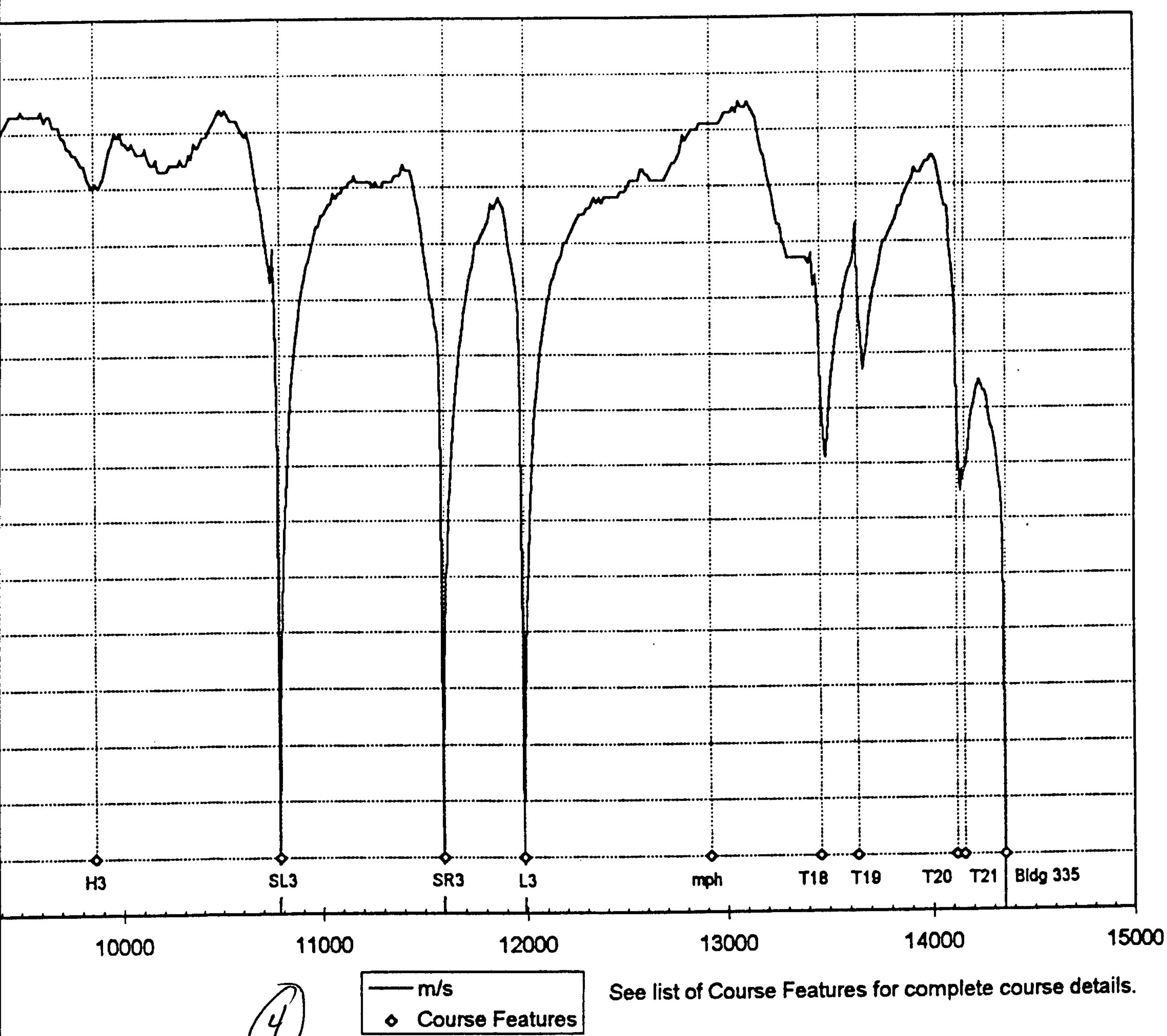

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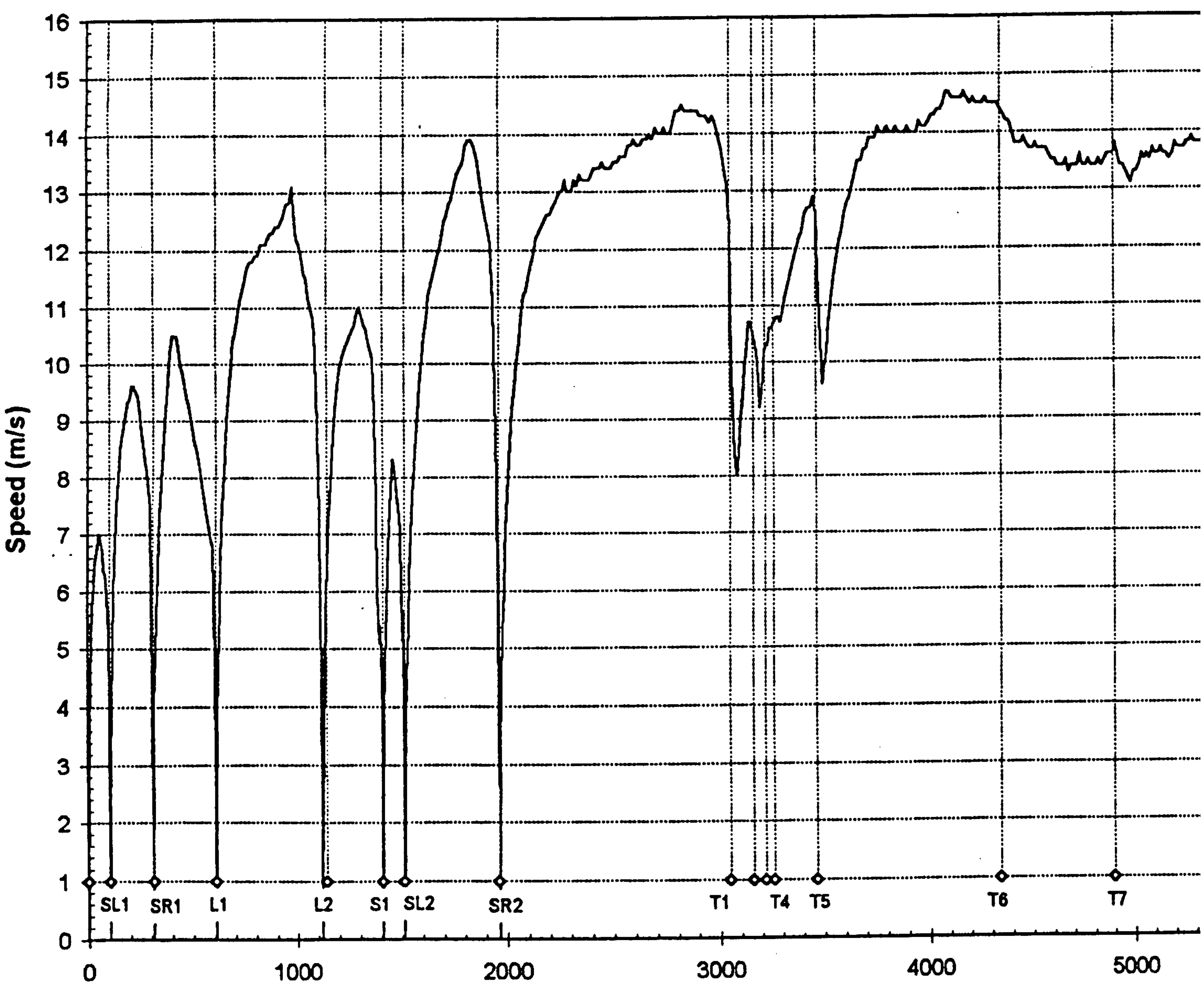
See list of Course Features for complete course details.

Chart

McClellan AFB EV Course.



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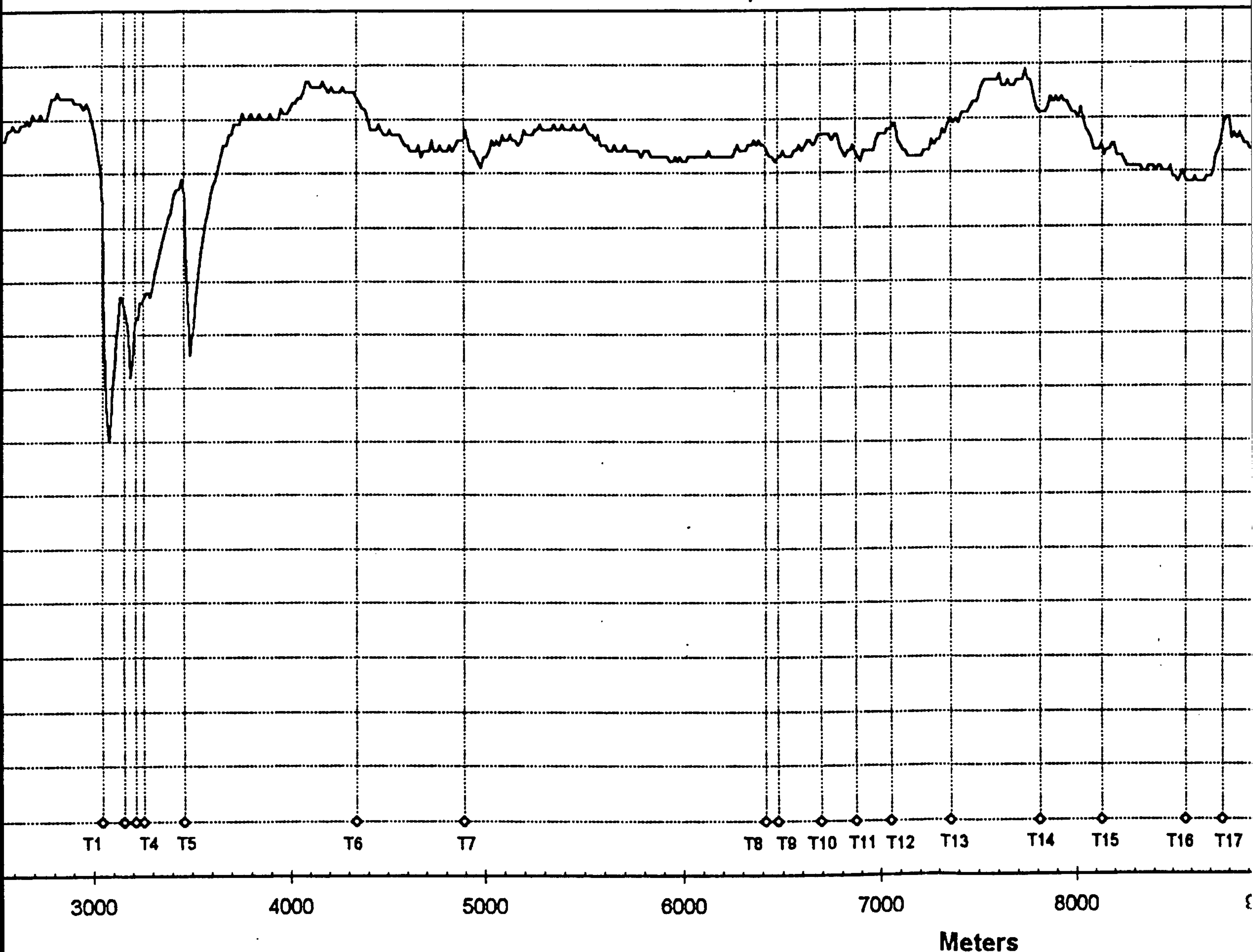

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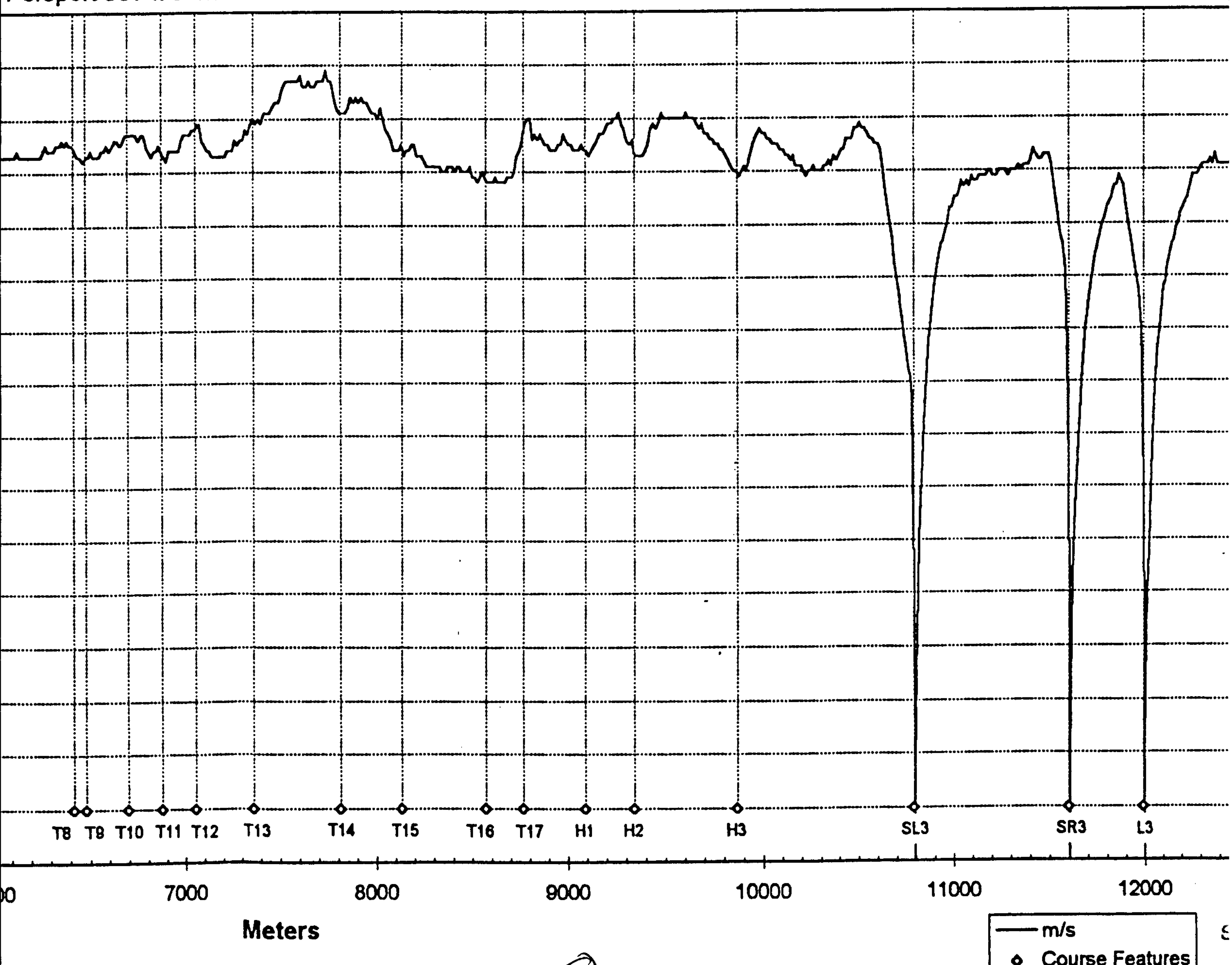

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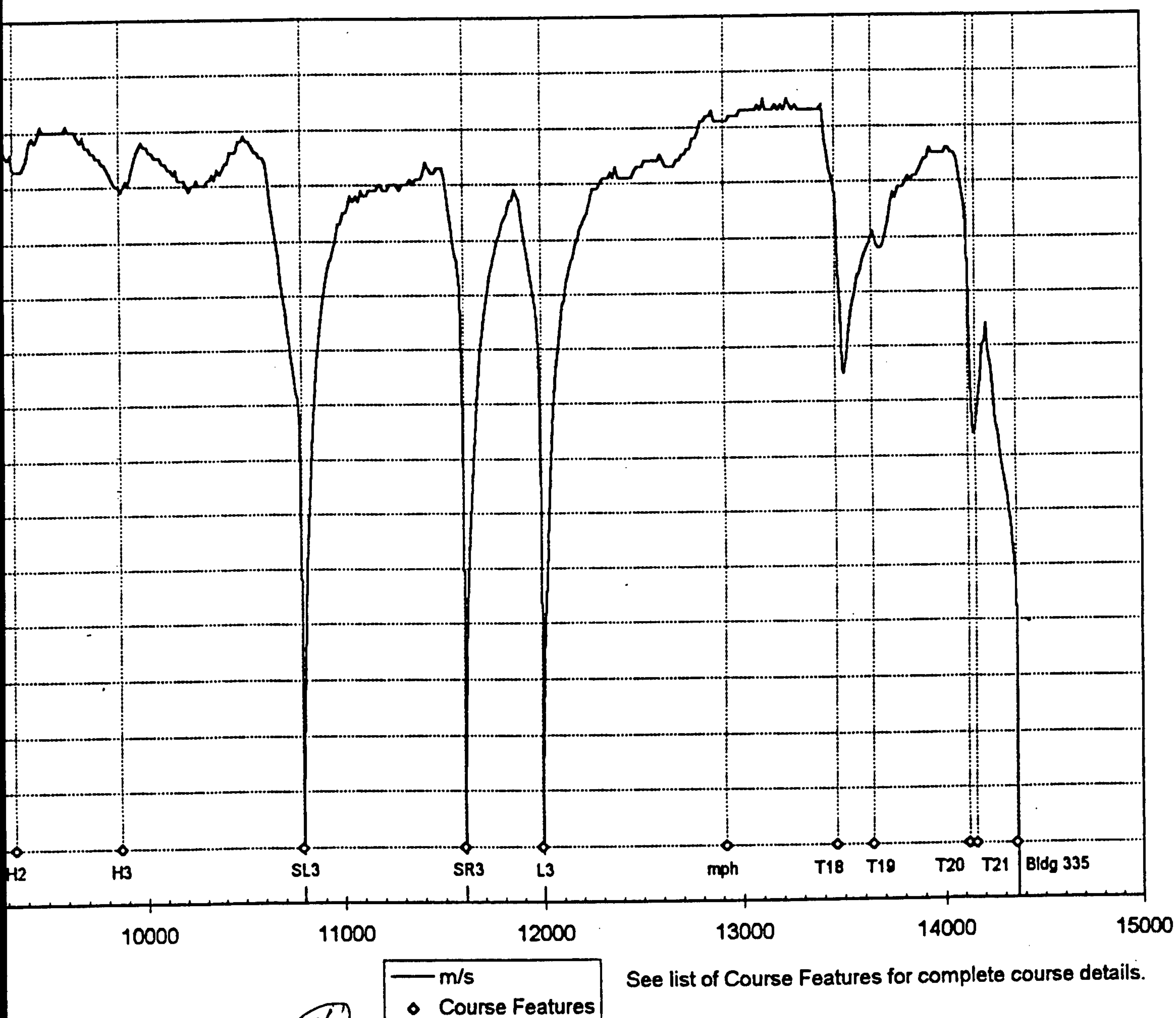

See list of Course Features for complete course details.

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Chart

Peregrin Drive Design Report
Prepared by: W.R. Warf, Pacific EV
Revision 0, 6/26/95

1.0 Summary:
The Drive System for the Peregrin has been designed to meet performance targets established for a neighborhood electric vehicle. These performance targets were derived from market information gathered as a part of the Neighborhood Electric Vehicle Demonstration and Development project, partly funded by SMUD and ARPA under Grant MDA-972-93-1-0025. The drive has been designed with reasonable cost, readily available components. Component selection took into account supplier reputation, location, and availability of technical support for the development phase of the Peregrin. The components selected can be integrated into a reliable, safe, low cost system which meets market place needs and satisfies applicable Federal Motor Vehicle Safety Standards (FMVSS).

The Drive System utilizes a series wound motor from Advanced DC and a Curtis Controller capable of regenerative braking with proportional control. A Club Car differential is used. This combination is expected to provide a drive capable of 36 mile range at 40 miles per hour based on present estimates of the prototype weight plus two passengers. Top speed is about 48 miles per hour depending on road conditions. Zero to 30 mile per hour acceleration will be possible in 10 seconds, although use of this maximum acceleration rate will adversely affect range. Maximum grade capability is estimated as 21%.

Other drive systems were evaluated and compared with the series wound motor and controller. These included an asynchronous AC drive, a brushless permanent magnet drive, and brush permanent magnet DC motor. While performance improvements would be realized with a more advanced and more efficient motor and controller system, we believe these systems will remain relatively expensive, and might preclude meeting the target market price for the Peregrin. A more advanced drive would also contribute to longer battery life and therefore lower operating cost, however based on analysis performed to date, the initial cost penalty is thought to be greater than the expected savings.

While more advanced drive systems have realized a significant amount of development and improvement in recent years, most of these systems are intended for heavier, freeway capable vehicles, and are designed for higher power output than is needed for the Peregrin. Most of these systems are also designed for higher operating voltages, which increases the complexity of the battery management systems and the cost of the battery pack. The Peregrin is designed to minimize overall operating cost including battery replacement cost. Our goal is a

neighborhood EV which is affordable, safe, convenient, and fun to drive for most non-freeway trips.

2.0 Scope:

This Drive Design Report provides a written account of the drive design. Market needs as derived from the City-el demonstration portion of the NEV project are reviewed in summary. Weight and Energy budgets and other design goals developed early in the project are updated. Cost and performance of the chosen system is compared with other drive systems which meet or are close to meeting the performance and weight goals for the Peregrin. Specific safety features of the present design are reviewed. Supplier capability and location is discussed. The design choices made in specific drive component selection and set points for the Curtis Controller are provided. The design of the reducing differential is described, along with the cost, weight and performance trade-offs considered.

The drive system selected for the Peregrin meets all performance goals with existing proven technology. The system should provide a cost effective, robust, reliable, and safe drive system.

3.0 Market Needs:

Neighborhood Electric Vehicle (NEV) market needs have been assessed through the demonstration of 37 City-el electric vehicles in the Sacramento area over the past 20 months. Some of the most significant findings are summarized in the following.

The City-el provides many of the attributes of an NEV, including convenient use, quiet operation, ease of parking, minimum infrastructure needs, low cost, and low energy use. The City-el is deficient mainly because of the three wheeled design. The City-el is not quite fast enough for use on inter-city through streets and expressways. It accommodates only one adult passenger, and has a rough ride and an uncomfortable seat. The City-el is a motorcycle, with some of the amenities of a conventional car. The City-el is less appealing to customers because of the need for a helmet. Because of it's three wheeled design it has handling which is acceptable for fewer prospective customers, and diligent warning of prospective customers is required even for a short demonstration. Most of our customers have found the range of the City-el (20-30 miles) acceptable.

Market surveys performed by Sandra McKee at DeVry University in Atlanta show that 70% of personal transportation can be accomplished without using the freeway, and that people typically drive 30-50 miles per hour in non-freeway travel. About 1/3 of respondents in this study stated that putting gas in the car was

the most bothersome part of car use. All respondents stated cars are too expensive, confirming that low cost is a very important purchase criteria.

3.1 Market Driven Drive Performance Goals:
Drive performance goals for the Peregrin were developed to provide maximum consumer acceptance within the Neighborhood Electric Vehicle Category, while retaining as many attributes of the City-el as possible. These improved performance goals can be summarized as follows:

- Improved Safety features, crash test capable
- Four Wheels
- Two Seats
  45 mile per hour top speed,
- Ability to keep up with traffic
  35 mile range
- Lowest possible cost

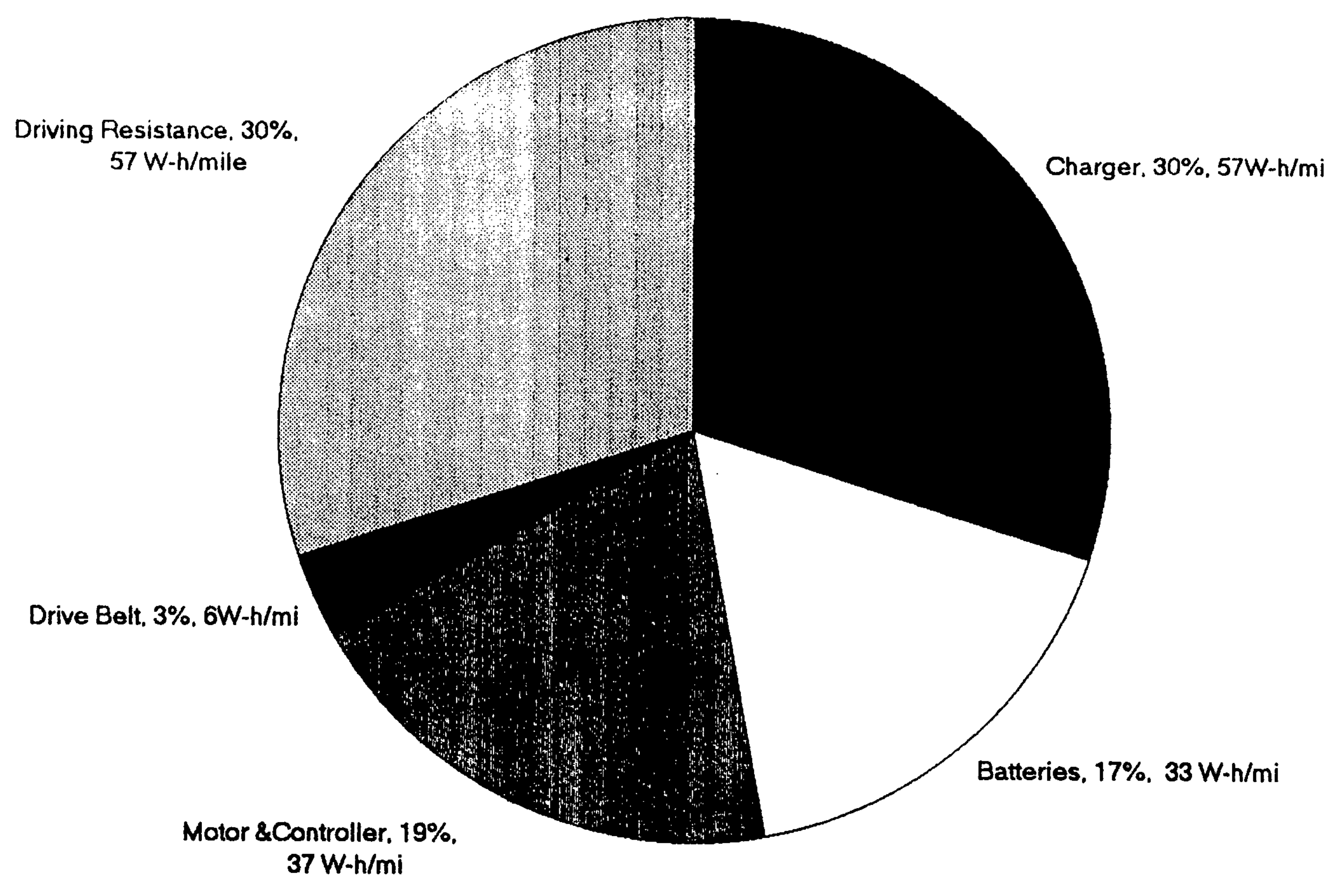
To improve safety a composite body-chassis has been designed, and a prototype shell is under construction. This new body chassis is designed to be capable of passing the crash tests prescribed in the FMVSS, and accordingly will be more substantial structurally than the City-el, and most importantly from a drive design standpoint, heavier. The Peregrin will have four wheels and two, comfortable seats and capacity to haul 100 kg of cargo plus two passengers. Through the drive design process, the latest weight estimates were combined with a target Cd*A drag factor of 0.5 m^2 (Cd=0.3, A=1.5 m^2) to provide the basis of a performance model for the Peregrin. Rolling resistance information from the Persport, 4 wheeled City-el was evaluated. The resulting performance model was used to evaluate different drive system choices.

4.0 Weight and Energy Budgets:

Early in the project weight and energy budgets were developed for the prototype NEV. These were used as design goals throughout the design process. These energy budgets were compared with the measured data from the City-el and component tests to provide a basis for sub-system selection. Figure 1 provides an idea of how the systems in the City-el use energy. The curb weight of the City-el is 660 lbs including charge transformer, and the battery mass fraction is 30%. The Peregrin prototype is expected to have a curb weight of 992 lbs, and a battery mass fraction of 40%. It is noted that the Persport 4 wheeled City-el weighs 695 lbs. The driving dynamics of the Persport is addressed in a separate report.

Early in the design process, we planned to use a brushless DC (sometimes called synchronous AC) drive system with rare earth magnets. These drives have a flat

Figure 1: City-el Systems Energy Use, Average per mile traveled, 190 W-h/mi total at plug



torque versus RPM curve, are quite efficient, and have the lowest possible motor weight because of the use of rare earth magnets. Figure 2 shows the energy budget for the early NEV concept which we expected to be capable of 140 AC W-h/mile. The vehicle weight modeled here is 400 kg curb weight plus one 80 kg passenger. After discussions with Parker Compumotor, Hathaway, Solectria, Western Technology Marketing, Wavedriver, Animatics, and others it was concluded that a brushless DC drive would cost $6000-$10,000 for the prototype, and that this cost could be reduced by about half in 1000 unit per year production. Non-recurring engineering was estimated by Animatics at about $20,000, however Animatics wanted to retain rights to the design, and did not want to provide project cost documentation and project contributions. Parker Compumotor declined participation. Since the production budget for the Peregrin drive is about $1200, the brushless DC drive was ruled out.

The drive system selected for the Peregrin is 10 kg heavier than our original target weight for the brushless DC drive, and has contributed to an overall weight increase for the prototype from early estimates of 400 kg to the present 450 kg estimate. The use of a series wound DC motor also necessitates a higher energy use for equivalent performance, however the energy use is still expected to be 167 AC W-h/mile, and 106 DC W-h/mile such that 34-36 mile range is available from a 3600 DC W-h (50-60%DOD) battery pack. Figure 3 shows the energy budget, updated for the present Peregrin design, with two passengers, and at an average 45 mph. Tabular data used for this pie chart is presented in Appendix 1. Estimated energy use per mile traveled at average speeds of 40 and 31 miles per are also presented in Appendix 1. These give range estimates of 34 and 47 miles, respectively. A performance comparison for a variety of drives in the Peregrin is presented in the next section of this design report.

5.0 Cost and Performance:

The Peregrin performance model was used to compare the probable performance of different candidate drive systems. Because Solectria components were judged to be representative of possible systems, and because motor-controller performance curves for these drives were readily available, Solectria components were used in the models and compared with the present drive system. Table 1 provides a summary of the performance and cost parameters considered for the drive systems which were the closest to our performance goals. Each drive presented in the table is discussed in the following.

In the first estimate, motor-controller systems were evaluated based on their ability to drive the Peregrin up a 20% grade with two passengers, and to accelerate from 0-30 mph in about 10 seconds given a system voltage of 72 Volts and a current limit from the batteries of 220 Amps. The motor must also have a torque versus

Figure 2: NEV Prototype Average Energy Use Engineering Goals, 140 W-h/mi total at plug

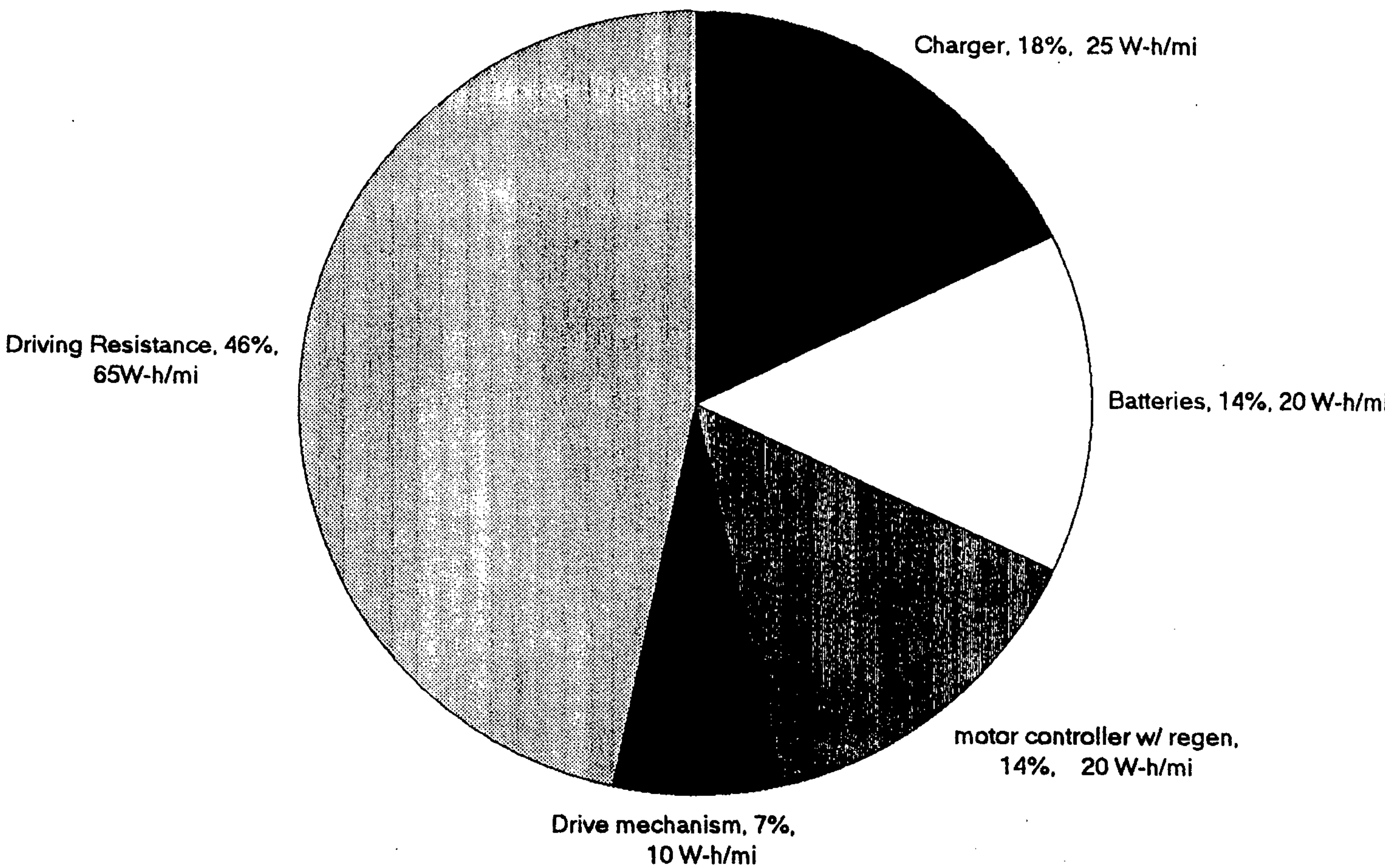
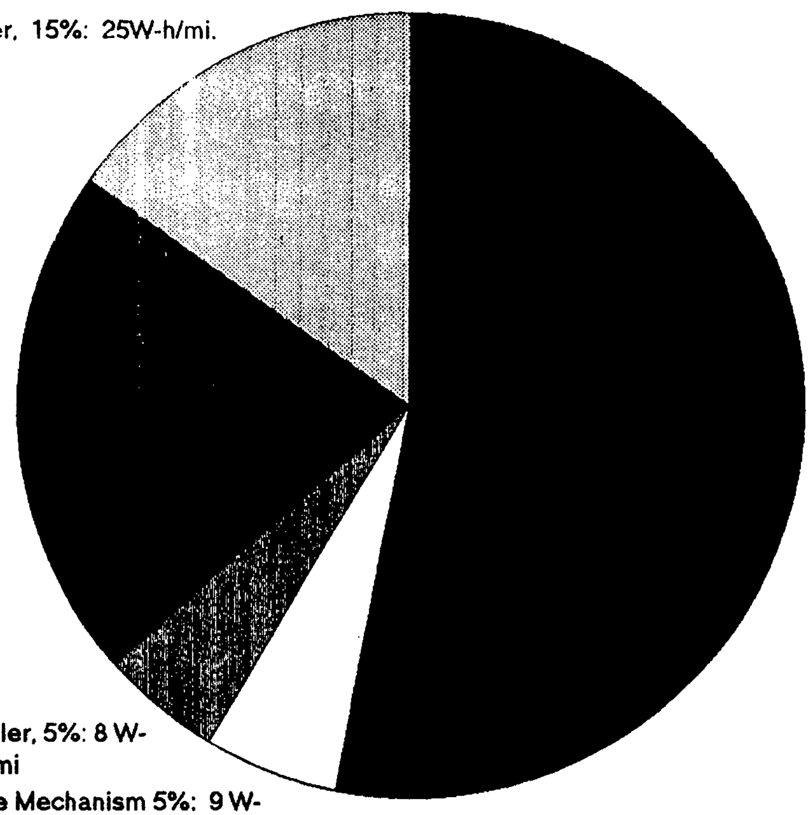


Figure 3: Peregrin AC Energy use for a 15 mile, 45 mph trip, 167 W-h/mile total



speed curve capable of a 72 km/h (45 mph) top speed without the use of a gear change. Although other systems were evaluated, Table 1 provides four drives which were closest to our performance needs, plus City-el performance figures for reference. The drives evaluated were from different drive types, namely series wound, brushless DC, AC induction, and Brush Permanent Magnet. These drives might be considered comparable to other motor controller combinations in the same type and power category. For example, the Brush Permanent Magnet motor BPM-8 is similar to the Lynch motor with respect to the shape of it's torque - speed curve. Although the Lynch motor provides higher torque, it may be limited to a lower peak RPM and might require a lower reduction ratio to meet our top speed benchmark. The Lynch motor is still in the prototype phase and is rather expensive compared to the BPM-8 or series wound system. It deserves further consideration in the future.

Only controllers which could provide proportional control of regenerative braking were considered, since this is judged mandatory for a light EV. Regen may provide a life benefit for the batteries and a range extension of about 10-15%.

Rolling and wind resistance power needed for the Peregrin derived from our performance model are provided graphically versus speed in Appendix 2. Worksheets for each Drive System considered are provided in Appendix 3. Appendix 4 includes system cost and weight worksheets. Each drive presented in Table 1 is discussed in the following.

5.1 Advanced DC, K91 series wound motor and Curtis 1209 R Controller: This drive was selected for the prototype primarily because of cost ($2800) and because both motor and controller are already developed and in regular production. While the BPM-8 system is less expensive, it would not provide both the gradeability and the top speed goals for the Peregrin without a multi speed gear box. The K91 + 1209R system should meet our production cost goal of $1200.

The Curtis Controller is a well developed and tested regenerative braking controller presently being sold only to Original Equipment Manufacturers (OEM's), mostly in Europe. The K-91 motor is commercially available from Advanced DC and from an established distribution system with stocking distributors. Both Curtis and Advanced DC have a good track record, and are located in the US. It is noted the product engineering group for this Curtis controller is in Dublin, California.

Other controllers which were considered for use with the Series wound motor include Cableform, Brusa, and Zappi. All of these appear to be advanced prototypes in limited production, and in every case the supplier is more distant than Curtis.

Table 1,Peregrin summary of drive comparisons

Parameter \ Motor	K91	BRLS-11	AC-12	BPM-8	City-el
Max Power (kW)	11.4	14.5	10.3	10.5	4.3
Max. Vehicle Speed (km/h)	78	80	67	50	55
Max Torque (N-m)	67.8	29	35	30	27
Speed at Max Torque. (km/h)	25	23	25	50	5
Acceleration, 0-50 km/h (sec)	10	10.5	14	12	24
Speed on 6% Grade (km/h)	60	80	45	50	36
Efficiency at 70 km/h cruise (%)	0.75	0.89	0.83	n/a	n/a
Batt. Current at 70 km/h (Amps)	65	56	60	n/a	n/a
Maximum Grade (%)	21	18	21	13	16
Reduction Ratio Used (value:1)	5.5	10	11	7.9	7.75
Cost for Prototype	$2,800	$7,110	$7,966	$2,440	-
Cost @ 1000/year	$1,287	$4,000	$3,000	$1,100	-
Weight of system w/o differential (kg)	38.7	13.6	32.8	27.7	-

This drive system is expected to draw an average of 60 Amps in normal NEV usage as seen with the City-el, and taking into account the fact that people will use the higher speed if it's available. The Peregrin will be able to maintain 35 mph (60 km/h) on a 6% grade, which is considered adequate. Top speed is expected to be 48 miles per hour, and maximum grade of 21% is possible depending on payload. As previously stated a range of 34 miles is predicted at 45 mph with a 3600 W-h battery pack to 50-60 % DOD.

The main problem with this drive system is the potential to draw higher currents from the battery than we originally intended. The series wound motor is relatively inefficient at higher currents compared to the other drives considered. The production 1209R controller from Curtis has a nominal current limit of 275 Amps, and Curtis is unwilling to reduce this for a prototype order of one unit. We expect some downward adjustment of the controller will be possible on the prototype. Other current limiting schemes can be considered and tested on the prototype, such as variable resistance in parallel with the drive potentiometer, as done in the City-el with the current limiting board.

The speed torque of the series wound motor drops off faster than the Brushless DC BRLS-11, and the speed up a 6% grade is lower; i.e. 60 km/h with the series motor and 80 km/h with the brushless DC. On a grade, the Brushless DC is also considerably more efficient. With the series wound motor higher current is drawn from the battery to produce equivalent torque at low speed and at higher speeds.

5.2 BRLS-11, Brushless DC Motor and Controller, Solectria:
James Worden told us that this product will be phased out, which is too bad because of it's high efficiency and low weight. The cost of this system and the probable cost of a comparable system from other suppliers with whom we had discussion precludes consideration for the Peregrin. The BRLS 11 could meet all performance goals given a current limit of 200 Amps, the addition of a series parallel switch, and with a motor wound for a 72 V system. This BRLS-11 system is almost 6 kg lighter than our original 28 kg weight goals for the drive, while the K-91 system is about 11 kg heavier. In 1000 units per year production an equivalent drive is estimated to cost about $2300 more than the K-91 system. This is roughly 5 replacement sets of batteries. The cruising current would be about 6-9 amps lower than the series motor, and is probably not enough of an improvement to justify the cost.

5.3 AC-12, AC Induction Motor and AC-220 Controller:
This motor was evaluated to assess how an AC drive might run in the Peregrin. The Solectria AC-12 is just a little too small (3 kW nominal, 11 kW peak) with

derating to a 72 Volt battery pack, and the AC-20 is a little too big. One advantage of these drives is the controller provides dash board signals for speed, brake lights, cooling fans, battery voltage meter, and ammeter, as well as very nice proportional control of regenerative braking. The AC-12 would probably provide adequate performance in the Peregrin with a higher voltage battery pack (4 kW nominal, 14 kW peak at 144 V) which would require a more elaborate battery management system, and necessitate a higher pack replacement cost. This drive is also considerably more expensive than the K-91, at almost $8000 each. It is unclear if the price of this drive will be reduced in the future, however numerous Japanese companies appear to working on 5-6 kW nominal and 12 kW Peak asynchronous AC drives, and perhaps these are worth investigating in the future. No known US company is producing a motor controller system for vehicles in this power range.

5.4 BPM-8 Brush Permanent Magnet Motor and DC-200 Controller, Solectria

This is a low cost, highly efficient drive. Without a multiple speed gearbox it does not have enough torque for the Peregrin, although it might provide nice performance in the 4 wheeled City-el. Note in Table 1 that a 7.9:1 ratio would allow a 13% grade and a 50 km/h (31 mph) top speed. With this ratio a respectable 0-30 mph time of 12 seconds could be realized, and a good 30 mph on a 6% grade would be expected. This motor might provide an efficiency and range benefit with a three speed transaxle.

6.0 Safety:

The safety features incorporated in the design of the Peregrin Drive System include the following.

6.1 Layout:

The layout of the Peregrin is such that all high voltage (72 V) wiring is in the battery and drive compartment of the vehicle, under the cargo bed behind the seats. A 12 V isolated control system operates all switches, and no high voltage wiring extends outside of the compartment with the exception of the 120 VAC line to the charger. The positive side of the battery pack is connected through a 150 Amp fuse to the normally open main contactor. This contactor is actuated by the key switch. Power from the key switch can be interrupted by the emergency off switch, the inertia switch, or the charger interlock relay.

6.2 Performance:

Performance requirements for the system were selected based on experience in driving City-el's in heavy Sacramento traffic. In short, the Peregrin drive system is designed to be able to keep up with City traffic. Driving more slowly, as with all

EV's should allow an extension of range (34 miles at 45 mph, 36 miles at 40 mph, 40+ miles at 31 mph... see Appendix 1).

6.3 Safety Interlocks:
The motor control system is highly interlocked for safety, as shown on the Drive System Schematic, PEV drawing number D- 00038. Features include a "high pedal disable" within the controller which prevents lurching of the vehicle if the forward reverse switch is actuated after a pedal is depressed. The system includes 4 contactor assemblies, main, drive, regen, and forward-reverse. The drive and regen contactors include switches on the drive and regen enable circuits to the controller. These are wired through switches on the accelerator and "decelerator" pedal, such that "drive" is possible only if the Regen Contactor is open and the accelerator switch is on. "Regen" is possible only if the accelerator switch is off, the regen switch is on, and the Drive Contactor is open. If both drive enables are provided to the controller, no operation occurs.

The Park-Reverse-Neutral, Forward Switch (Clockwise) satisfies FMVSS 102, although a specific park actuator is yet to be worked out. This switch will eventually be interlocked to prevent shifting out of Park without a key in the ignition, and to prevent shifting from forward to reverse while in motion.

6.4 Main Contactor:
A key switch in series with both an emergency off switch and an inertia switch operates the normally open main contactor. Activating the emergency off or the inertia switch opens the high voltage circuit to the drive. The main contactor circuit is also interrupted when the charger is plugged in to prevent driving while charging.

6.5 Differential:
A differential is used to prevent the inner wheel from over driving in turns as it covers less distance than the outer wheel. The use of a differential is mandatory for the good handling needed for safety.

6.6 A note about permanent magnet motors:
Permanent magnet motors connected to the drive wheels without a clutch may pose a safety concern due to the high voltage generated when a coil is rotated in a the magnetic field without a load connected. Some care is required when controller failures might allow high voltage to be developed by the motor on over-run (down-hill) with a controller problem. This potential problem suggests Series wound or AC induction motors may have a safety advantage over permanent magnet motors. Julian Styles of Wavedriver told us this is the reason the Wave Driver controller

was designed with asynchronous as opposed to synchronous (fixed field-permanent magnet) motors.

7.0 Drive System Design, Motor-Controller System

After selection of the motor and controller, the balance of the system design follows Curtis' recommendations as a starting point. Curtis specifies the system installation with regard to the various contactors and switches, such that the safety features of the Controller are not violated. Our installation design follows Curtis' specification for a 12 V isolated control system. The schematic is provided on PEV drawing D-00038. Some features of the design have been discussed above, and additional details follow.

7.1 Contactors:

7.1.1 Main Contactor:

The Main Contactor is an Albright SW180B-xx 12CO contactor. A Kilovac contactor was considered for this component, however an appropriately sized contactor is actually a little heavier than the Albright model. The SW180B is rated for 200 Amps for 15 minutes. Since 200 amps should be roughly equivalent to the 15 minute discharge rate for the batteries, this contactor is acceptable. The contactor is equipped with magnetic blowouts to minimize arcing. A twelve volt, continuous operation coil was selected, with a coil suppression diode.

7.1.2 Forward Reverse Contactor:

The Forward-Reverse Contactor is an SW192B-2 12CO, and was recommended by Curtis to carry the currents between the controller and the motor. This paired contactor is furnished with interconnecting links to accomplish forward reverse switching. It is specified with magnetic blowouts, continuous operation coils and suppression diodes. Note that continuous operation coils draw less power than intermittent duty coils. The total power for main, drive or regen, and forward or reverse contactors is about 80 W.

7.1.3 Drive and Regen Contactors:

The Drive and Regen Contactors are Albright SW200A-16 12CO. These were recommended by Curtis to carry currents between the controller and the motor. These contactors are fitted with auxiliary switches to interlock the drive and regen functions, as described in the above section on safety. The SW192 is rated at 250 Amps continuous. Twelve volt, continuous operation coils were selected, with coil suppression diodes.

7.2 Regen Relay:
A small DPDT relay is used to switch the forward reverse contactors when the regen function is enabled. In forward-regen, the reverse contactor is closed, and in reverse-regen, the forward contactor is closed.

7.3 Potentiometers:
Curtis potentiometers were selected. A PB-8 0-5k Ohm 3 wire potentiometer is used for regenerative braking, and a PB-6 0-5k Ohm 2 wire is used for acceleration. Both of these are equipped with auxiliary switches to accomplish the previously described drive-regen interlock function.

7.4 Controller:
A Curtis 1209R-11xx controller has been selected, as previously discussed. The following information was specified to Curtis:
Battery System Voltage: 72 V
Battery Capacity: 80 A-h at the 2 hour rate
Battery Type: (6) Trojan 30-XHS 12 V, 130 A-h at the 20 hour rate
Operating temperature range: -10C to 50 C
Current Limit: 220 Amps (Curtis exception: will be 275 Amp plus or minus)
Regen Current Limit: 100 Amps
Regen Voltage Limit: 85.5 V (2.375 VPC)
Isolated, 12 V control wiring
High Pedal disable included
Drive Acceleration Rate: 1.0 seconds from 0-100% duty factor at full throttle.

Some discussion follows.

7.4.1 Regenerative Braking Voltage and Current Limits:
100 Amps was chosen for the current limit for regenerative braking. This appears to be a good starting point, and should not be too much for the batteries. Proportional control of Regen with this current limit will allow braking torque's from 0 to 10 ft-lbs (13.58 N-m) at the motor when the batteries are sufficiently discharged to allow full regen current. This provides a deceleration rate of at least 0.46 m/s^2. The regen voltage limit is chosen a little below Curtis' recommendation of 2.4 Volts Per Cell (VPC) based on review of GNB and Horizon charge acceptance data, to protect the batteries from damage. It is likely the Trojan batteries could accept a higher regen voltage limit and currents, and this is a conservative setting. The voltage limit is used by the controller to further limit regen current depending on the state of charge of the batteries, to prevent overcharging on regen.

7.4.2 Drive Acceleration Rate:

Curtis recommends a drive acceleration rate for 0-100% duty cycle of 1.5 seconds as standard. Based on driving the City-el, which is equipped with a Curtis Controller, a slightly quicker (1 second) acceleration rate was chosen to allow a more responsive accelerator. This will allow the vehicle operator to apply torque to the rear wheels more quickly while cornering, and should make the Peregrin more responsive. The lag present in the City-el sometimes makes the accelerator feel a little slow to come on.

7.5 Motor:

An Advanced DC k-91 series wound motor was selected. This motor is a standard Advanced DC product which costs $630 retail. Production cost is expected to be around $350-$400 in 1000 unit per year procurements. Some characteristics of the K-91 are listed below:

Weight: 26.4 kg (58 lbs)
Armature Resistance: .012 Ohms at 75 F
Field Resistance: .013 Ohms at 75 F
Continuous Rating: 7.2 kW
1 Hour Thermal rating: 130 Amps
5 minute thermal rating: 275 Amps
Stall Current at rated voltage: Estimate 325-360 A
Bearings are double sealed and lubricated with high temperature grease.
No load test: 12 V, 14 Amps: 2400 RPM Minimum
Low load: 70 V, 140 Amps, 12 ft-lbs: specification: 3500-3950 RPM
Full Load: 67 V, 275 Amps, 20 ft-lb, specification: 2900-3350 RPM

As previously discussed, this motor will provide appropriate performance in the Peregrin. Testing of the Peregrin prototype will be performed to confirm operation as expected.

8.0 Differential:

A differential is used to allow fully independent rear suspension, and to rigidly support the motor to the chassis as sprung weight. Two reducing differentials were considered, the Brusa/Solectria Differential, or the Club Car differential. The club car differential was chosen because of weight. price. and availability.

The differential used in the Horlacher with the gt20 motor is standard with 10:1 reduction, and other ratios may be available. This differential weighs 14 kg (30.8 lbs) and would fit in the Peregrin. Price is about $1350. This differential is

designed for higher power drives, and would provide a good safety margin. With the present series wound motor. a ratio of 5.5:1 - 6.1:1 is needed, and modification would be required.

The Club Car differential is made in Japan for Club Car, and weighs 9.5 kg with a 12.28:1 ratio. Retail cost was $692 and the differential was received from stock in one week after ordering. The cast aluminum differential housing is bolted to steel axle housings for the golf cart. For the Peregrin these are removed, and an adapter fabricated to house stub shafts. These stub shafts incorporate splines to fit the differential, and a universal joint to match the half shafts.

For the prototype Peregrin, a Gates Polychain drive belt is fitted between the motor and the differential input shaft, again with an adapter plate. A bearing is fitted to the adapter plate to take the belt loads. This arrangement is good for development, since other motors and drive ratios can be fitted during prototype testing. For production, the differential will be modified such that the motor is bolted directly to the differential.

The Club Car differential is well made, and is designed to handle about 25-30 N-m from the golf cart motor. Because of the speedup ratio of 2-2.2 chosen to give a final drive of 6.14:1 or 5.58:1, the torque on the motor input shaft from the Advance DC motor is reduced to the correct range. Axle shaft input splines in the unit are appropriately sized. There is a concern about allowable speed on the input shaft, however this will be evaluated by testing.

An outline drawing of the differential is provided in PEV sketch SK102, along with a bill of material.

8.1 Ratio Selection:
As a result of final detail design of the Gates Polychain belt drive including specific sprocket and belt selection, a ratio of 5.62: 1 is used as seen on SK-102. As mentioned above, ratios can be changed relatively easily by changing sprockets on the motor or differential, and the detail design facilitates this.

In the design process, models at 5.5: 1 and 6.5:1 were evaluated. Both have merit, however taller 5.5 to 1 ratio leaves peak torque available to a higher speed (25 vs. 22 mph), gives about the same acceleration (0-30 mph in 10 seconds), and puts the motor's peak efficiency from 35 - 45 mph. Maximum grade is 21%, compared to about 25% with a 6.5:1 ratio. For hilly terrain, or lower speed driving with more acceleration cycles, the lower ratio may be preferable, however this can be evaluated in driving the prototype. Range should be better with the taller ratio, depending on driving habits.

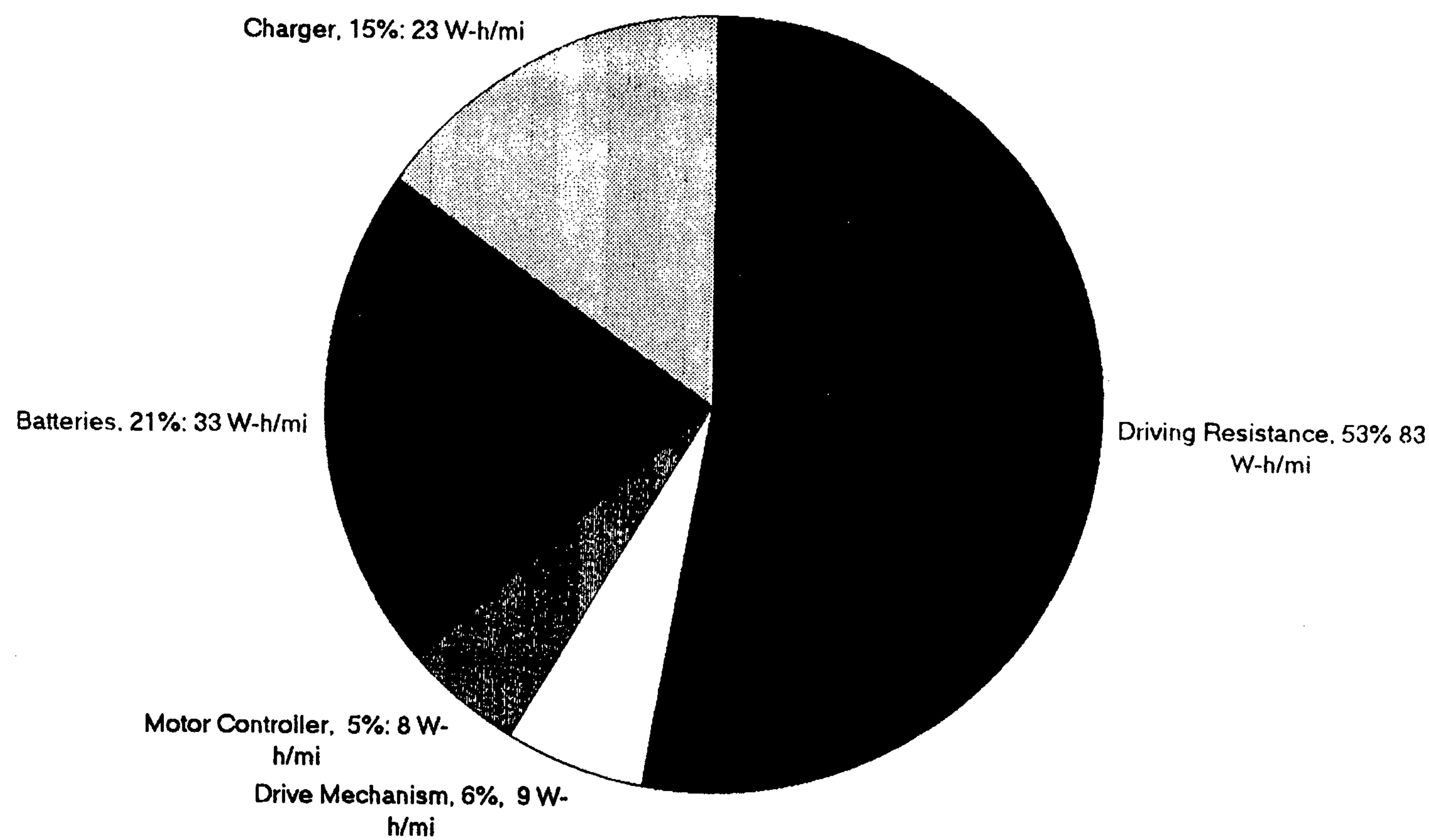
Driving 45 mph for 15 mi, .333 hours				% AC	W-h/mile	
	Average power (Watts)	Average current (Amps)	energy (W-h)	energy		
Driving Resistance	4000	55.56	1332	53%	89	
motor losses	78	1.08	26	1%	2	
drive losses	400	5.56	133	5%	9	
controller losses	223.9	3.11	75	3%	5	
Contactors	80	1.11	27	1%	2	
Total battery discha	4781.9	66.42	1592	64%	106	DC W-h/mi
Recharge Energy			2498		167	AC W-h/mi
Charger Losses			375	15%	25	
Battery Losses			531	21%	35	
Total Recharge Energy, (AC)			2498	100%	167	

Notes:

Allowable Discharge: (DC Watt-hours)	3600		(50 A-h)
Theoretical Range: (miles)	34		
Charging Speed with 1kW charger	7.07	miles/hour of charging	

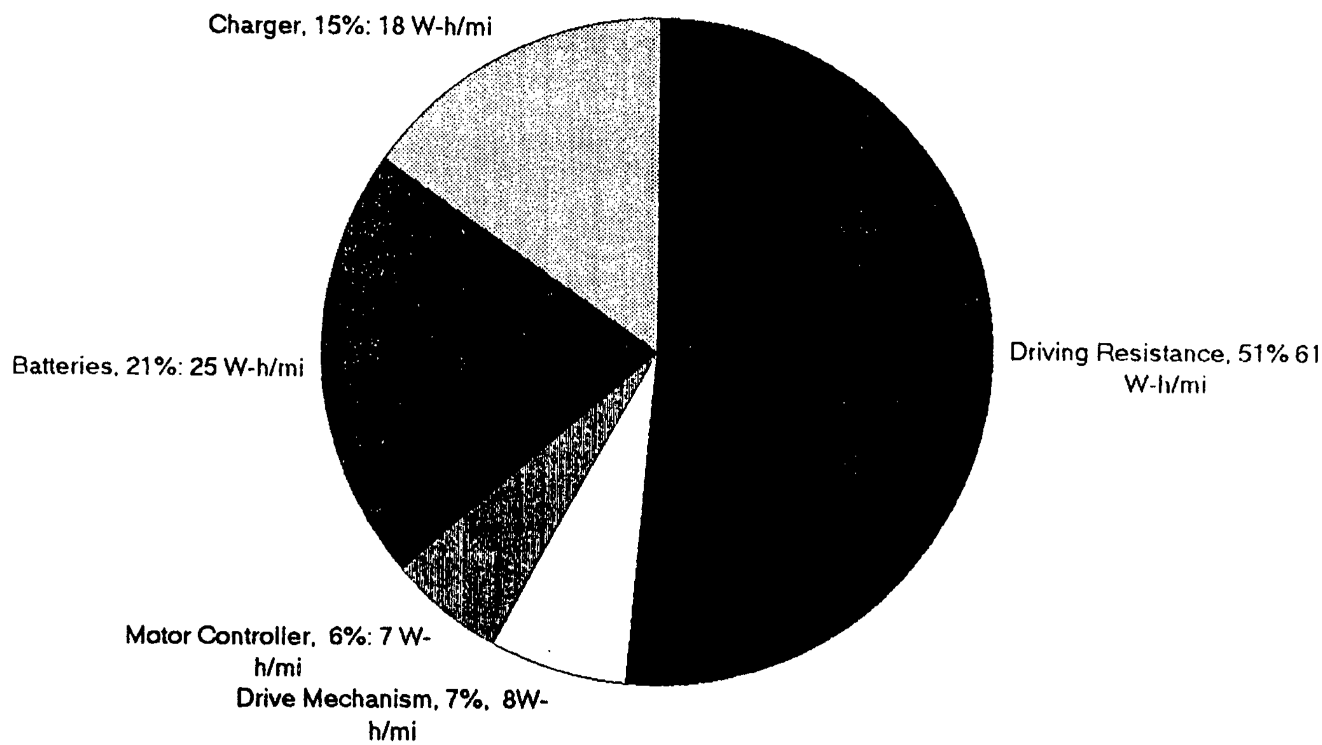
Driving 40 mph for 15 mi, .375 hours				% AC	W-h/mile	
	Average power (Watts)	Average current (Amps)	energy (W-h)	energy		
Driving Resistance	3300	45.83	1238	53%	83	
motor losses	53	0.74	20	1%	1	
drive losses	360	5.00	135	6%	9	
controller losses	185.65	2.58	70	3%	5	
Contactors	80	1.11	30	1%	2	
Total battery discha	3978.65	55.26	1492	63%	99	DC W-h/mi
Recharge Energy			2340		156	AC W-h/mi
Charger Losses			351	15%	23	
Battery Losses			497	22%	33	
Total Recharge Energy, (AC)			2340	100%	156	
Notes:						
Allowable Discharge: (DC W-h)			3600		(50 A-h)	
Theoretical range: Miles			36			
Charging Speed with 1kW charger			7.54	miles/hour of charging		

Peregrin AC Energy Use for a 15 mile trip at 40 mph. 156 W-h/mi.

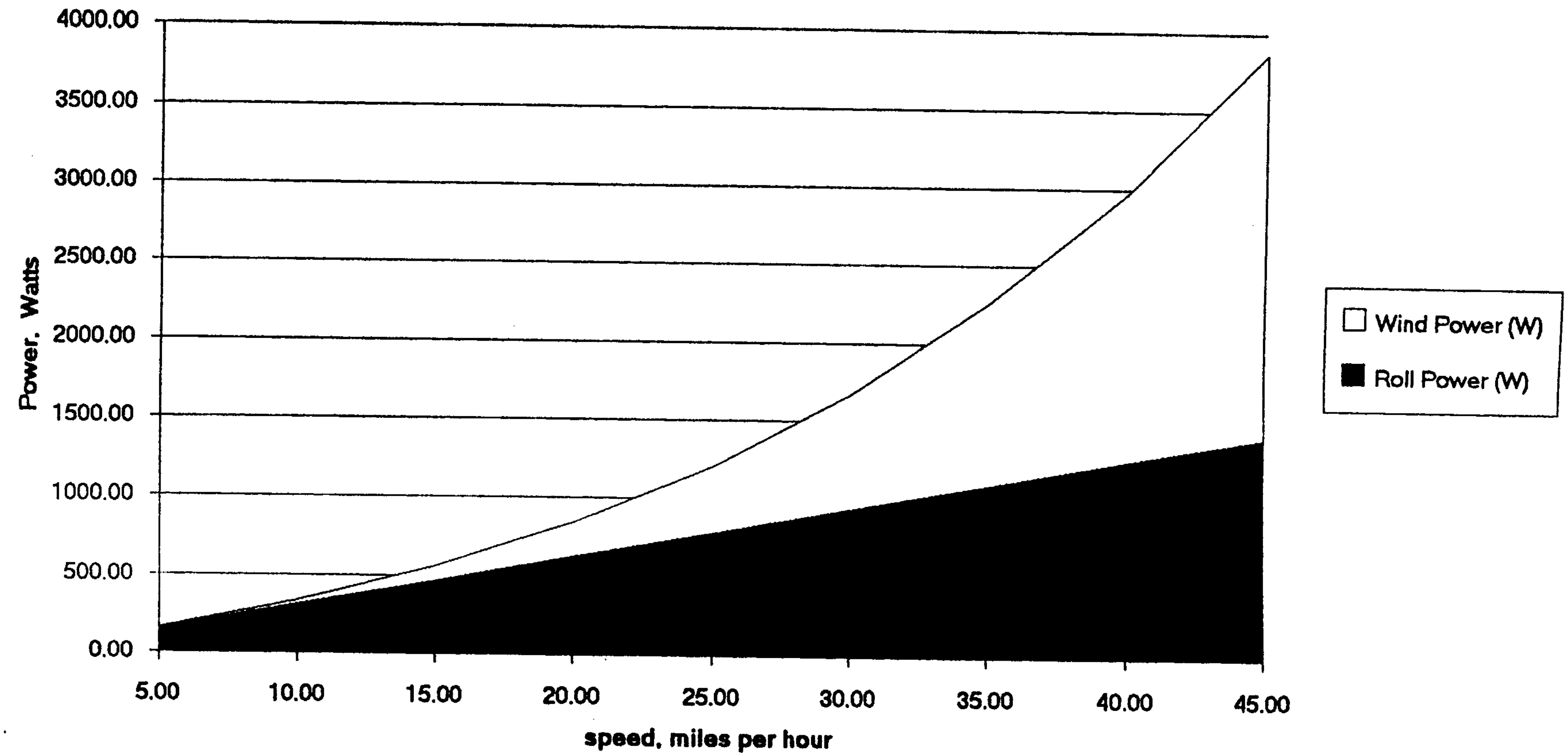


Driving 31 mph for 15 mi, .484 hours				% AC	W-h/mile	
	Average power (Watts)	Average current (Amps)	energy (W-h)	energy		
Driving Resistance	1895	26.32	917	51%	61	
motor losses	17	0.24	8	0%	1	
drive losses	250	3.47	121	7%	8	
controller losses	108.1	1.50	52	3%	3	
Contactors	80	1.11	39	2%	3	
Total battery discha	2350.1	32.64	1137	64%	76	DC W-h/mi
Recharge Energy			1784		119	AC W-h/mi
Charger Losses			268	15%	18	
Battery Losses			379	21%	25	
Total Recharge Energy, (AC)			1784	100%	119	
Notes:						
Allowable Discharge: (DC W-h)			3600		(50 A-h)	
Theoretical range: Miles			47			
Charging Speed with 1kW charger			9.89	miles/hour of charging		

Peregrin AC Energy Use for a 15 mile trip at 31 mph, 119 W-h/mi.



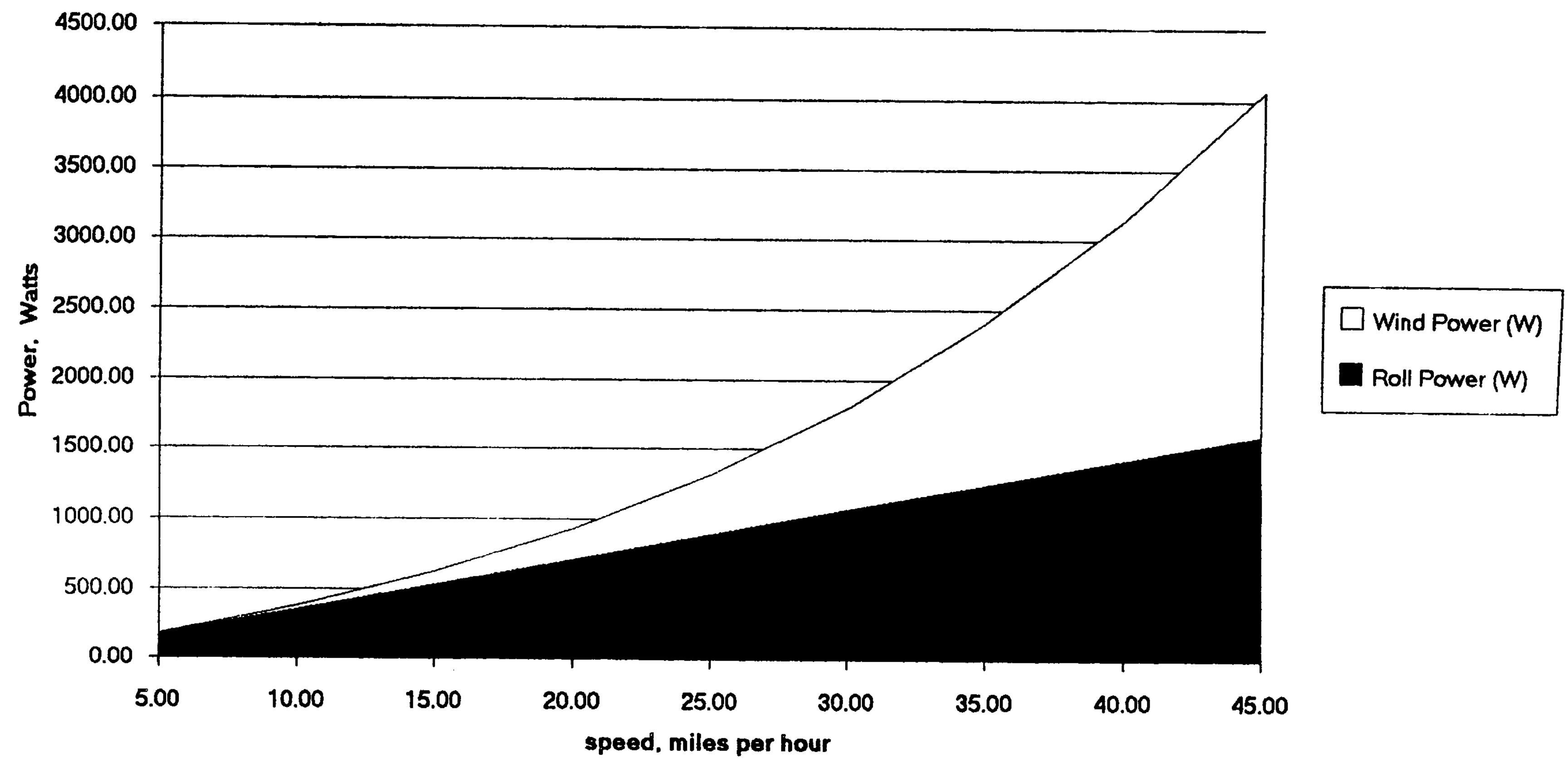
Rolling Resistance Plus Wind Resistance vs Speed, for Peregrin, one passenger (Cd*A = 0.5, F-roll = 70 N)



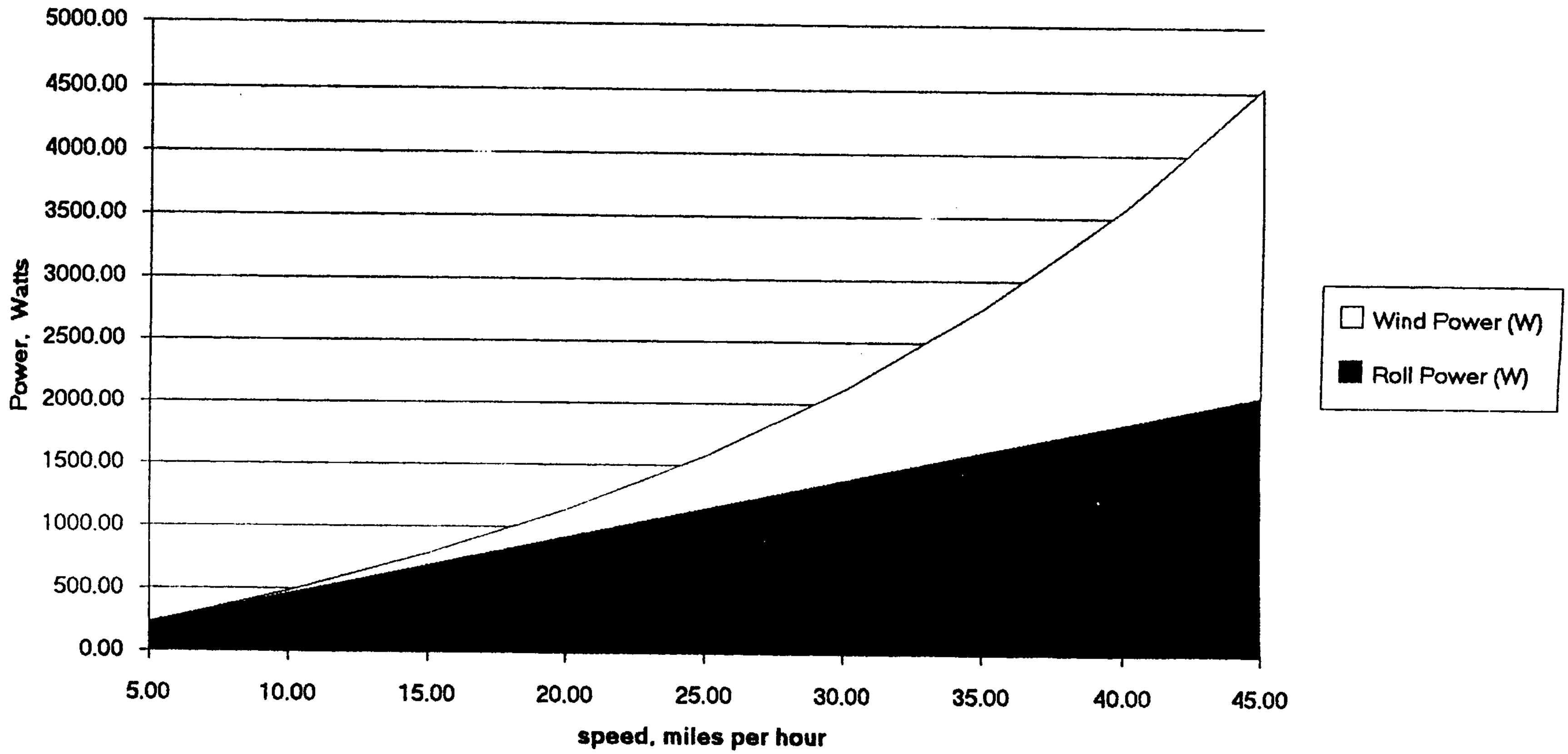
6/22/95

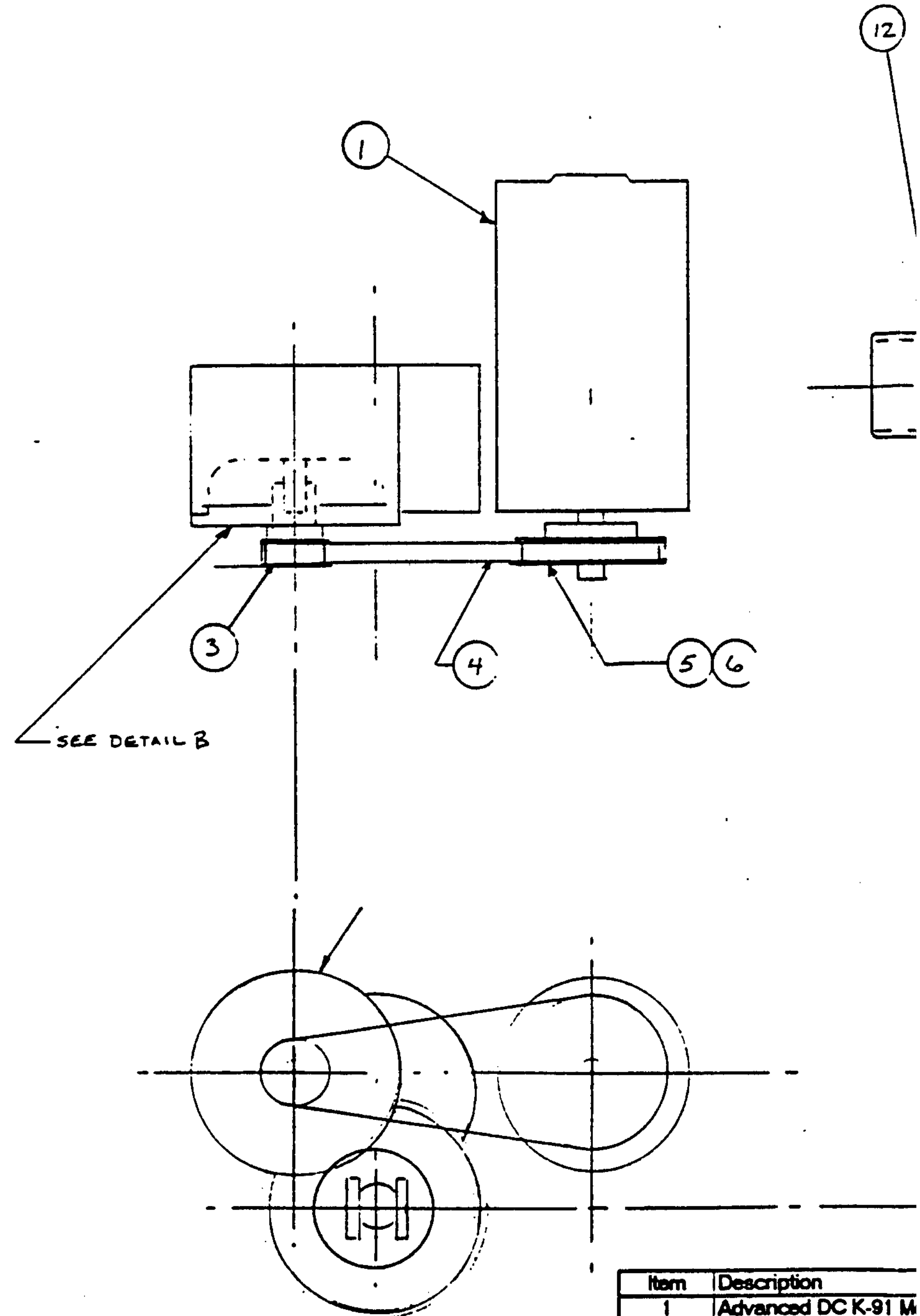
Appendix 2, 1 of 3

Rolling Resistance Plus Wind Resistance vs Speed, for Peregrin, two passengers (Cd*A = 0.5, F-roll = 80 N)



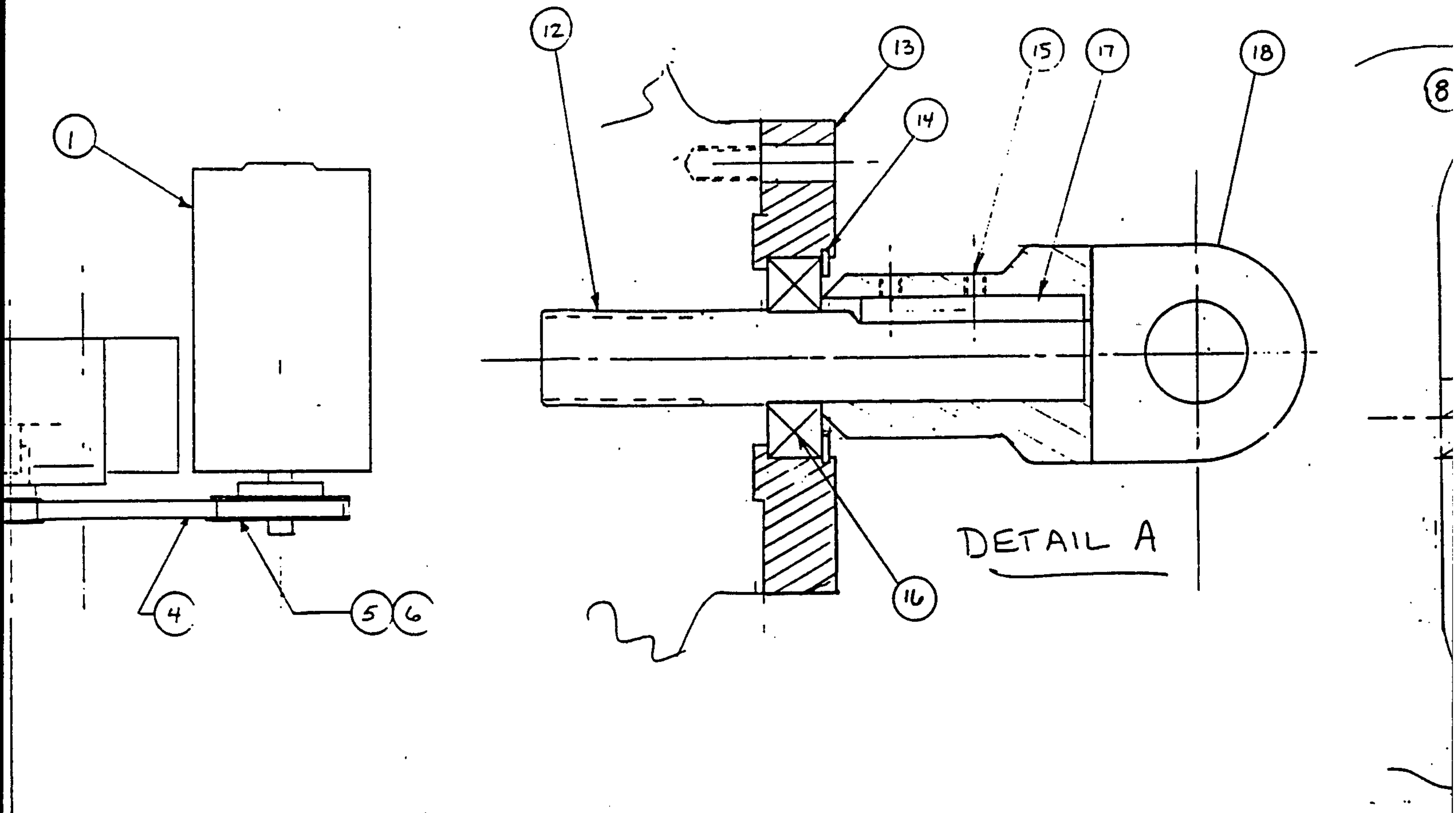
Rolling Resistance Plus Wind Resistance vs Speed, for Peregrin, at 750 kg GAVWR (Cd*A = 0.5, F-roll =100 N)

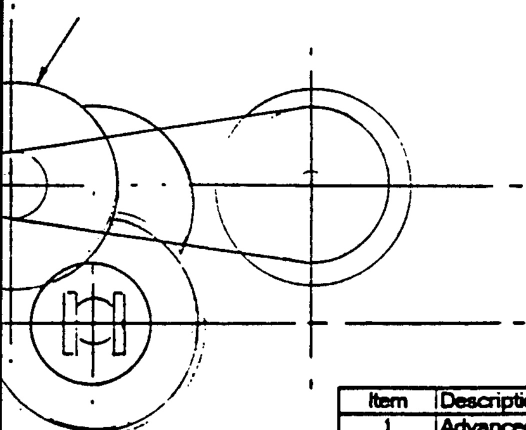


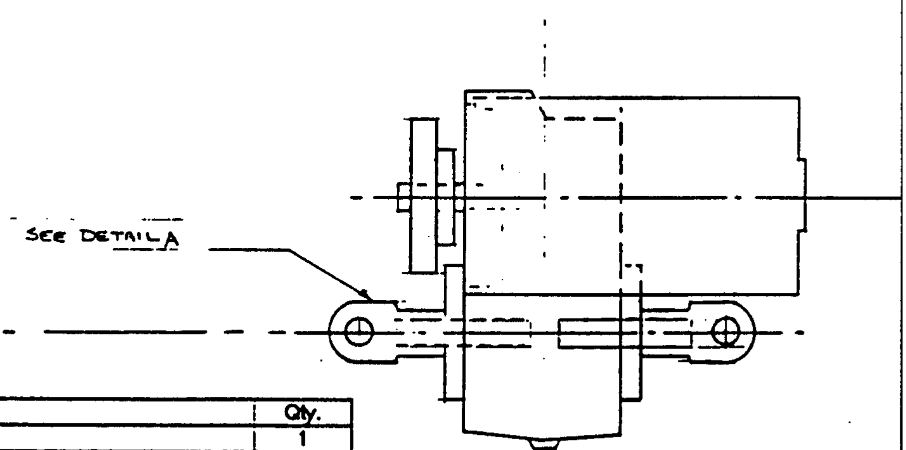


Item	Description
1	Advanced DC K-91 M
2	Differential, Club Car
3	Sprocket, Gates 8M-2
4	Belt, Gates 8M-800-1
5	Sprocket, Gates 8M-4
6	QD Bushing, SDS wit
7	Bearing, Federal Mog
8	Snap Ring, Tru-Arc N
9	Roll Pin, Alloy Steel, 3
10	Adapter, Differential I
11	Bearing Plate, Differe
12	Output shaft, Differen
13	Bearing Plate, differe
14	Snap Ring, Tru-Arc N
15	Set Screw, socket hea
16	Bearing, Federal Mog
17	Key, 1/4" square x 2"
18	Yoke, Output Shaft, C

1

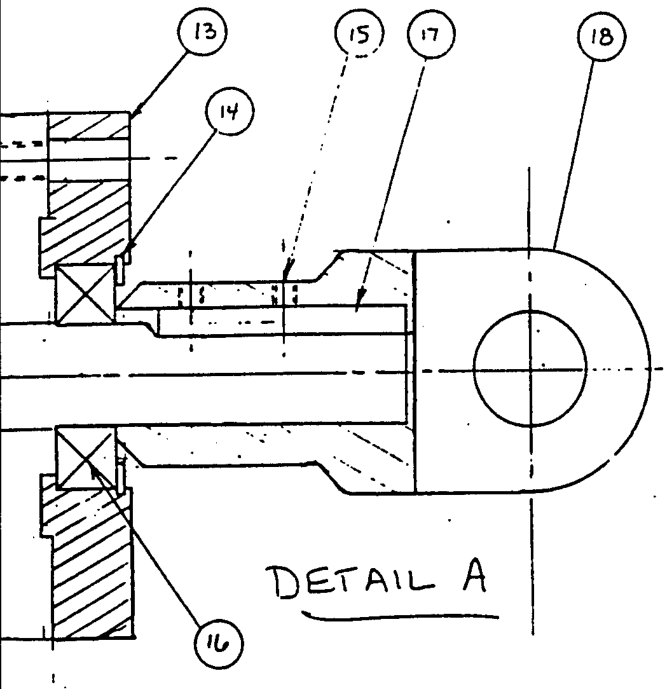




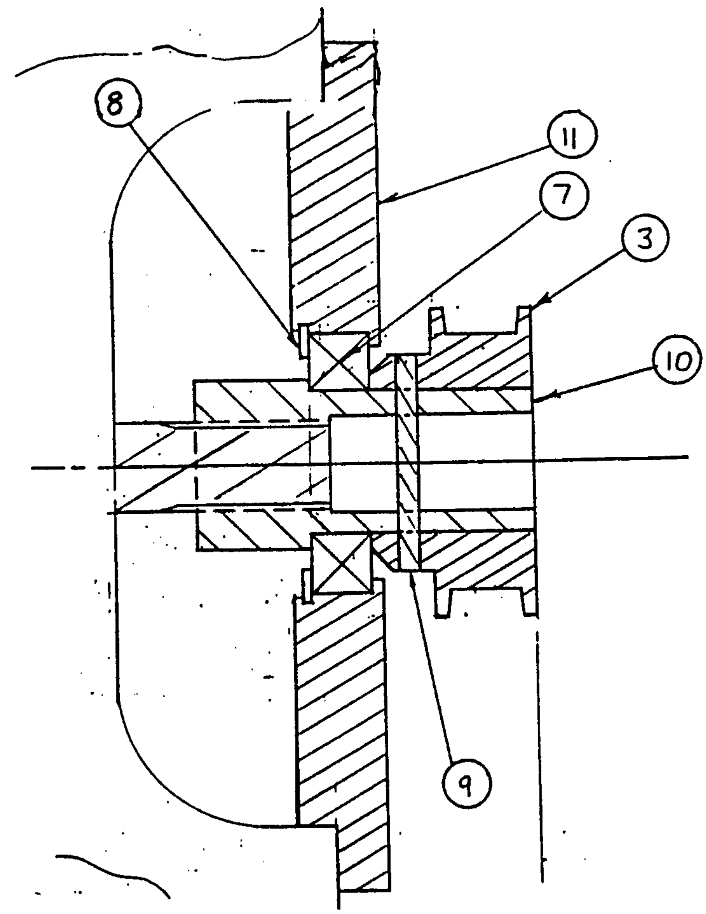


Item	Description	Qty.
1	Advanced DC K-91 Motor	1
2	Differential, Club Car	1
3	Sprocket, Gates 8M-22S-12, Steel, BTS	1
4	Belt, Gates 8M-800-12, 31.50 Pitch Length, 100 Tooth	1
5	Sprocket, Gates 8M-48S-12, 48 Tooth, Aluminum	1
6	QD Bushing, SDS with 7/8" bore & 3/16 key	1
7	Bearing, Federal Mogul 106 SS	1
8	Snap Ring, Tru-Arc N5000-218	1
9	Roll Pin, Alloy Steel, 3/16" dia. 1.75" long	1
10	Adapter, Differential Input Shaft, PEV A-00039	1
11	Bearing Plate, Differential Input shaft, PEV B-00040	1
12	Output shaft, Differential, PEV A-00041	2
13	Bearing Plate, differential output shaft, PEV B-00042	2
14	Snap Ring, Tru-Arc N5000-187	2
15	Set Screw, socket head cup pt. alloy steel, 10-32 x3/8 L	4
16	Bearing, Federal Mogul R-14 SS	2
17	Key, 1/4" square x 2" long, alloy steel	2
18	Yoke, Output Shaft, CR UJ1752, Modify per PEV A-00C	2

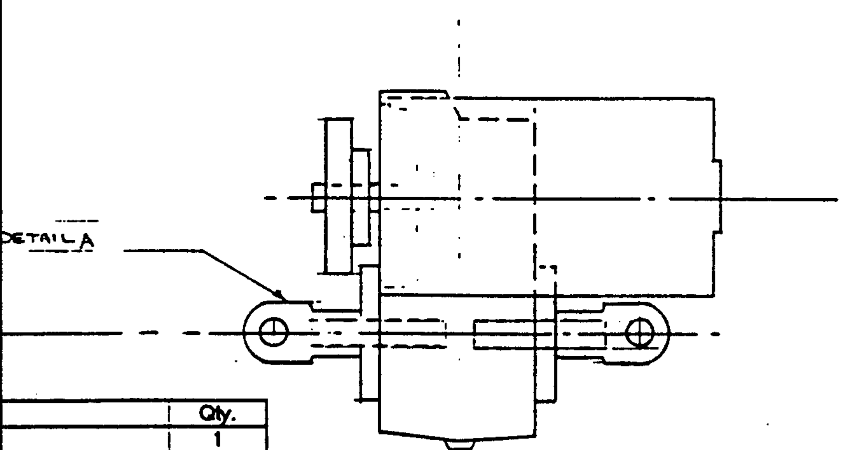
ITEM	QTY.	MATERIAL DE
THIRD ANGLE PROJECTION		SCALE:
TOLERANCES: X.X: X.XX: X.XXX: ANGLES:		DATE: 6/24/9
		DRIVE
		USED ON:
		NEXT ASSEMBL



DETAIL A



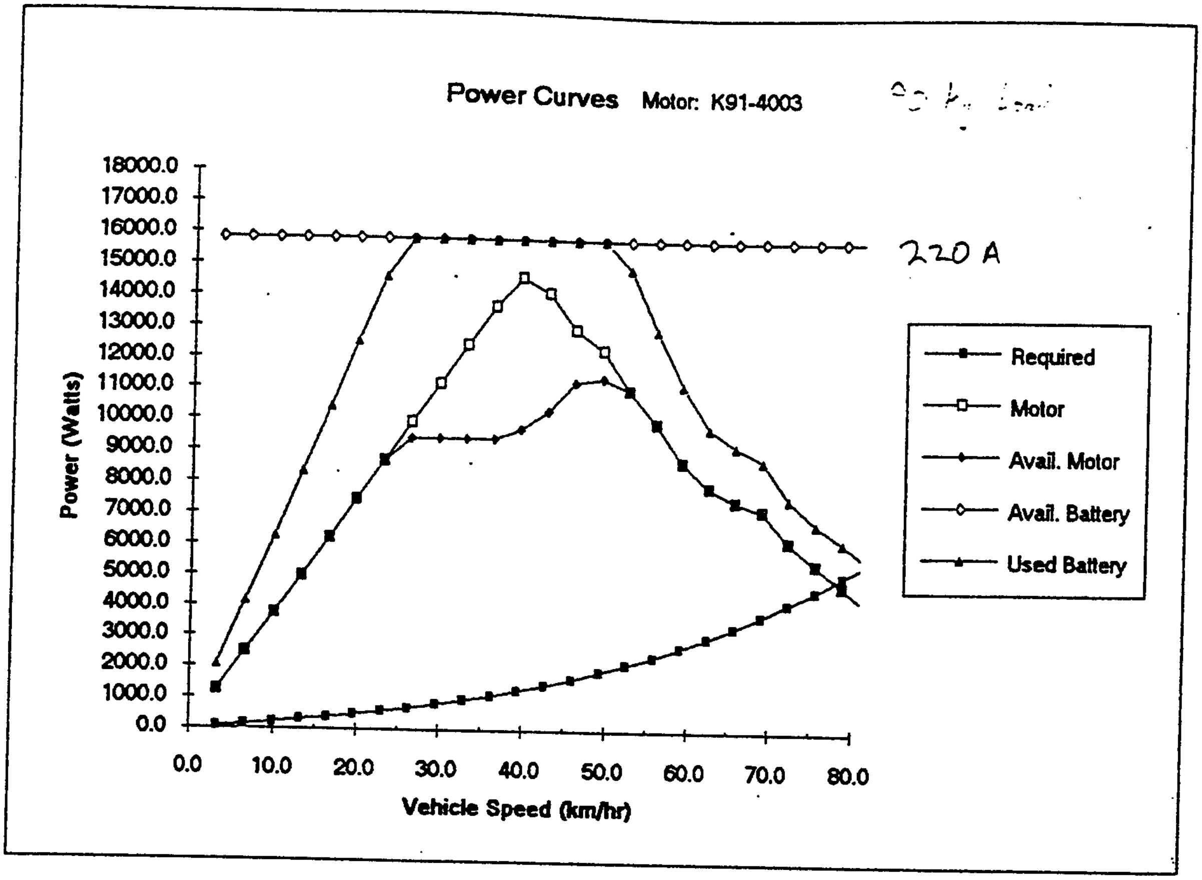
DETAIL B

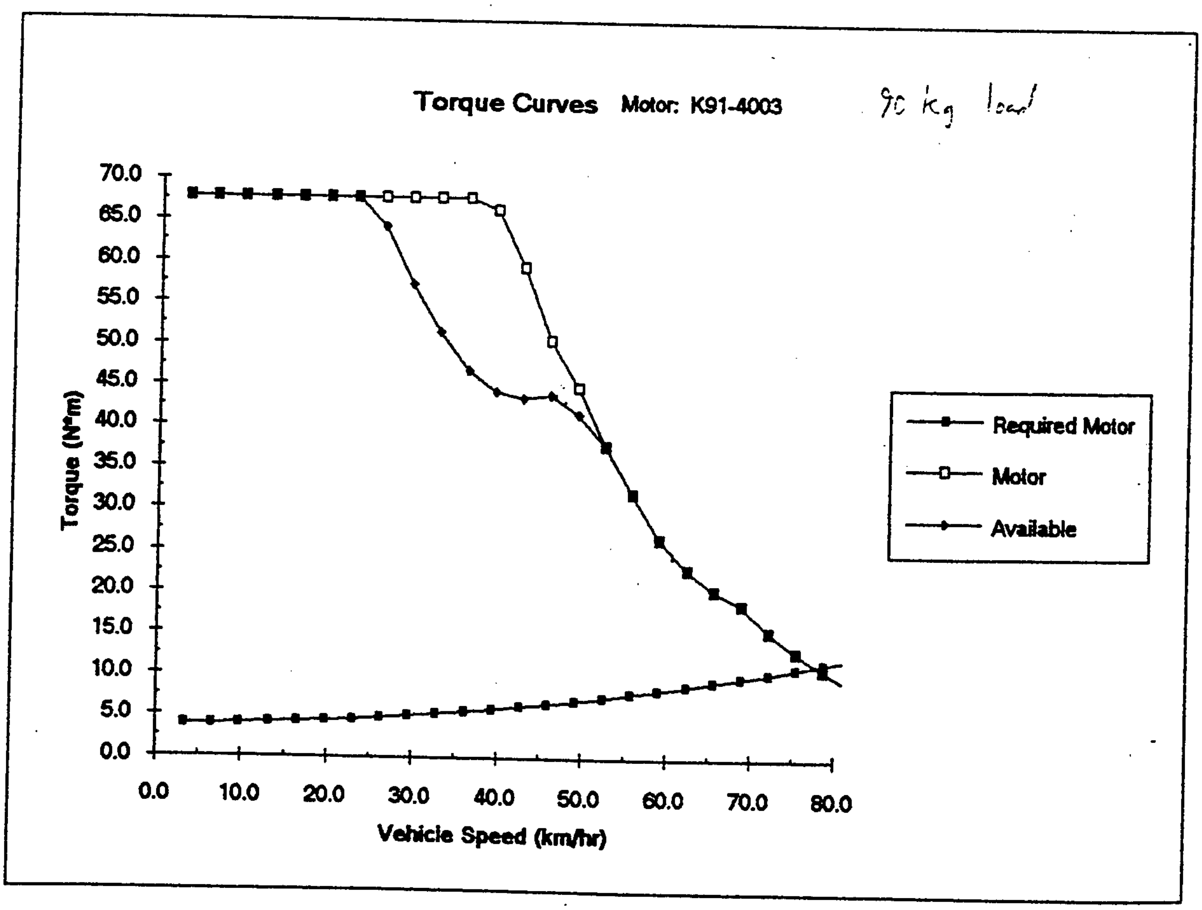


	Qty.
	1
	1
TS	1
ength, 100 Tooth	1
n. Aluminum	1
16 key	1
	1
	1
ong	1
A-00039	1
PEV B-00040	1
41	2
. PEV B-00042	2
	2
steel, 10-32 x3/8 L	4
	2
	2
ify per PEV A-000	2

ITEM	QTY.	MATERIAL DESCRIPTION		
THIRD ANGLE PROJECTION		PACIFIC ELECTRIC VEHICLES 8500 WEYAND AVE., SACRAMENTO, CA. 95828 FAX: 916-381-2189, PHONE: 916-381-3509		
		SCALE:	APPROVED BY:	DRAWN BY:
TOLERANCES:		DATE: 6/24/95	WRWANG	WANG
X.X: X.XX: X.XXX:		DRIVE ASSY, MOTOR & DIFFERENTIAL		
		USED ON: PEREGRIN	DRAWING NUMBER:	REV.
ANGLES:		NEXT ASSEMBLY:	SK 102	

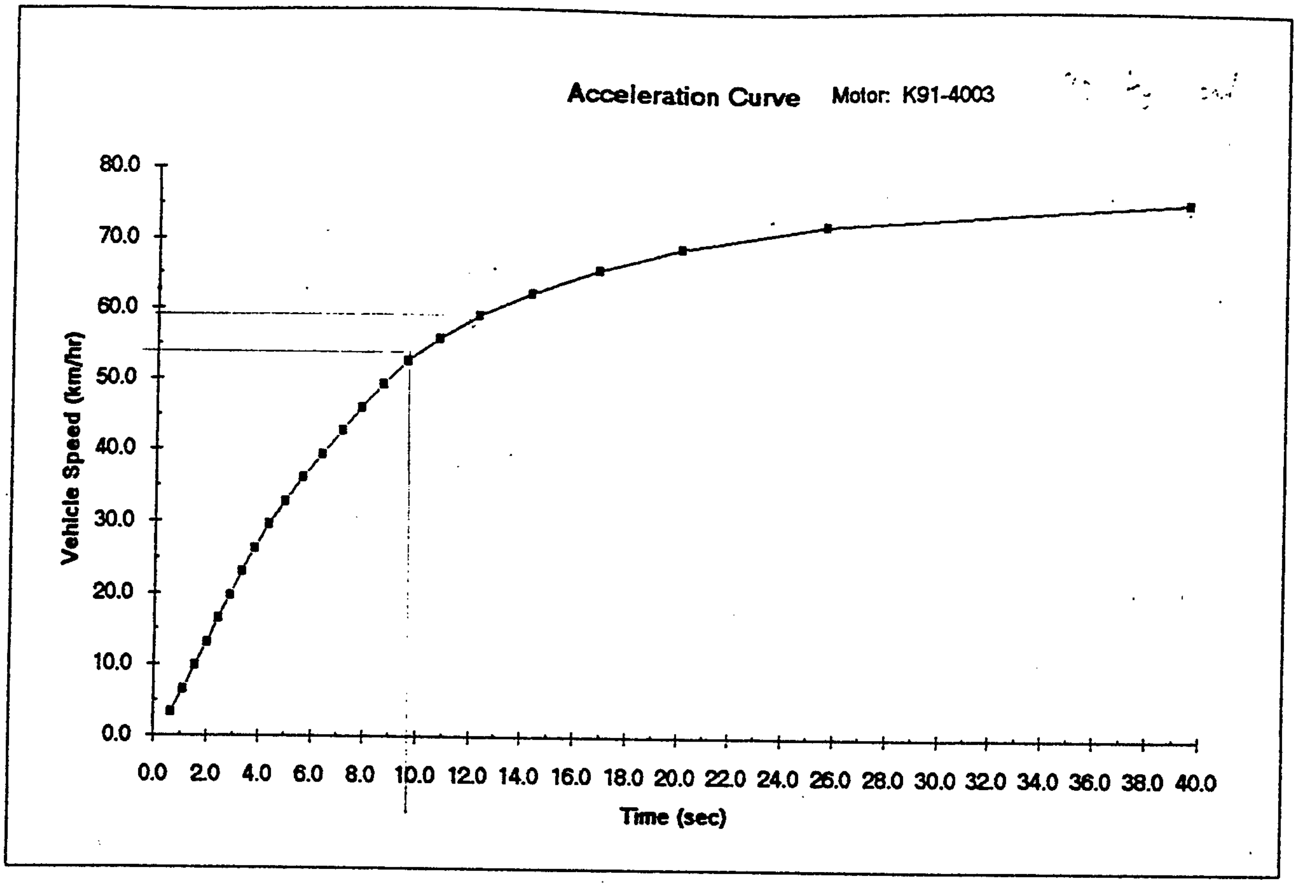
Case 1 5.5





Appendix 3

A3-1



5.5 ratio
90 Kg LOAD
220 A
case 1

A3-2

motor MAX Power 15.206 KW

MAX Torque 67 N·m

Pacific EV Vehicle Performance Model

Motor: K91-4003

Print Date: 2-9-95

Motor Speed (rpm)	175	350	525	700	875	1050	1225	1400	1575
Max Motor Torque (N*m)	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8
Eff. at Max Power (%)	62%	62%	62%	62%	62%	62%	62%	62%	62%
Motor Speed (rad/s)	18.3	36.7	55.0	73.3	91.6	110.0	128.3	146.6	164.9
Max Motor Power (W)	1242.5	2485.0	3727.5	4970.0	6212.5	7455.0	8697.5	9940.0	11182.5

Drive Ratio	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Wheel Speed (rad/s)	3.3	6.7	10.0	13.3	16.7	20.0	23.3	26.7	30.0
Wheel Speed (rpm)	31.8	63.6	95.5	127.3	159.1	190.9	222.7	254.5	286.4
Tire Diameter (m)	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
Vehicle Speed (km/hr)	3.3	6.6	9.8	13.1	16.4	19.7	23.0	26.2	29.5
Drag Coeff. Cd	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Frontal Area (m^2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Air Density (kg/m^3)	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
Head Wind (km/hr)	0	0	0	0	0	0	0	0	0
F wind (N)	0.2	0.9	2.0	3.6	5.6	8.1	11.0	14.4	18.2
Percent Grade	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vehicle Mass (kg)	400	400	400	400	400	400	400	400	400
Passenger + Cargo Mass (kg)	90	90	90	90	90	90	90	90	90
Total Mass (kg)	490	490	490	490	490	490	490	490	490
Crr1 (Rolling Resistance)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
F grade (N)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F roll (N)	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3
Crr2 (Wheel Windage)	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
F windage (N)	0.2	0.4	0.5	0.7	0.9	1.1	1.3	1.5	1.6
F total (N)	67.7	68.6	69.9	71.6	73.8	76.5	79.6	83.1	87.1
Wheel Power (W)	61.7	125.0	191.0	261.1	336.4	418.2	507.7	606.1	714.7
Wheel Torque (N*m)	18.5	18.8	19.1	19.6	20.2	20.9	21.8	22.7	23.8
Mechanical Eff.	87%	87%	87%	87%	87%	87%	87%	87%	87%
Required Motor Power (W)	70.9	143.6	219.6	300.1	386.7	480.7	583.5	696.6	821.5
Required Motor Torque (N*m)	3.9	3.9	4.0	4.1	4.2	4.4	4.5	4.8	5.0

Nom. Batt. Voltage (V)	72	72	72	72	72	72	72	72	72
Max Batt. Current (A)	220	220	220	220	220	220	220	220	220
Max Batt Power (W)	15840	15840	15840	15840	15840	15840	15840	15840	15840
Amp. Power (W)	2087.5	4175.1	6262.6	8350.1	10437.7	12525.2	14612.7	15840.0	15840.0
Amp. Current (A)	29.0	58.0	87.0	116.0	145.0	174.0	203.0	220.0	220.0
Amplifier Eff. (from Graph?)	96%	96%	96%	96%	96%	96%	96%	96%	96%
Electrical Power (W)	2004.0	4008.1	6012.1	8016.1	10020.2	12024.2	14028.2	15206.4	15206.4
Motor Current (A)	27.8	55.7	83.5	111.3	139.2	167.0	194.8	211.2	211.2
Max Avail. Motor Power (W)	1242.5	2485.0	3727.5	4970.0	6212.5	7455.0	8697.5	9428.0	9428.0
Max Avail. Motor Torque (N*m)	67.8	67.8	67.8	67.8	67.8	67.8	67.8	64.3	57.2

km (Rotational Inertia)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Max. Wheel Torque (N*m)	324.4	324.4	324.4	324.4	324.4	324.4	324.4	307.7	273.5
Max. Wheel Force (N)	1186.2	1186.2	1186.2	1186.2	1186.2	1186.2	1186.2	1125.1	1000.1
Accel. (m/s^2)	2.08	2.07	2.07	2.07	2.06	2.06	2.05	1.93	1.69
Accel Time (s)	0.7	1.1	1.5	2.0	2.4	2.9	3.3	3.8	4.3

A3-3

1750	1925	2100	2275	2450	2625	2800	2975	3150	3325	3500	3675	
67.8	67.8	66.4	59.3	50.5	44.7	37.6	31.9	26.4	22.7	20.3	18.6	
62%	62%	64%	68%	74%	75%	77%	80%	81%	84%	84%	85%	
183.3	201.6	219.9	238.2	256.6	274.9	293.2	311.5	329.9	348.2	366.5	384.8	
12425.0	13667.5	14602.1	14127.5	12956.4	12287.5	11024.9	9938.2	8708.5	7904.0	7440.3	7158.1	

5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	
33.3	36.7	40.0	43.3	46.6	50.0	53.3	56.6	60.0	63.3	66.6	70.0	
318.2	350.0	381.8	413.6	445.5	477.3	509.1	540.9	572.7	604.5	636.4	668.2	
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	
32.8	36.1	39.4	42.6	45.9	49.2	52.5	55.8	59.1	62.3	65.6	68.9	speed
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	
0	0	0	0	0	0	0	0	0	0	0	0	
22.5	27.2	32.3	38.0	44.0	50.5	57.5	64.9	72.8	81.1	89.8	99.0	Fw
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
400	400	400	400	400	400	400	400	400	400	400	400	
90	90	90	90	90	90	90	90	90	90	90	90	
490	490	490	490	490	490	490	490	490	490	490	490	
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	
1.8	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.3	3.5	3.7	3.8	
91.6	96.5	101.8	107.6	113.9	120.6	127.7	135.3	143.4	151.9	160.8	170.2	
834.6	967.2	1113.6	1275.1	1452.9	1648.2	1862.3	2096.3	2351.6	2629.3	2930.7	3256.9	
25.0	26.4	27.9	29.4	31.1	33.0	34.9	37.0	39.2	41.5	44.0	46.5	
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	
959.3	1111.7	1280.0	1465.6	1670.0	1894.5	2140.6	2409.6	2703.0	3022.2	3368.6	3743.6	
5.2	5.5	5.8	6.2	6.5	6.9	7.3	7.7	8.2	8.7	9.2	9.7	

72	72	72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
15840.0	15840.0	15840.0	15840.0	15840.0	15840.0	14914.6	12940.3	11199.2	9801.6	9226.6	8772.2
220.0	220.0	220.0	220.0	220.0	220.0	207.1	179.7	155.5	136.1	128.1	121.8
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
15206.4	15206.4	15206.4	15206.4	15206.4	15206.4	14318.0	12422.7	10751.2	9409.5	8857.5	8421.3
211.2	211.2	211.2	211.2	211.2	211.2	198.9	172.5	149.3	130.7	123.0	117.0
9428.0	9428.0	9732.1	10340.4	11252.7	11404.8	11024.9	9938.2	8708.5	7904.0	7440.3	7158.1
51.4	46.8	44.3	43.4	43.9	41.5	37.6	31.9	26.4	22.7	20.3	18.6

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
246.2	223.8	211.8	207.7	209.9	198.5	179.9	152.6	126.3	108.6	97.1	89.0
900.1	818.2	774.3	759.4	767.3	725.9	657.8	558.1	461.9	397.1	355.2	325.4
1.50	1.34	1.25	1.21	1.21	1.12	0.98	0.78	0.59	0.46	0.36	0.29
4.9	5.6	6.3	7.1	7.8	8.7	9.6	10.7	12.3	14.3	16.8	20.0

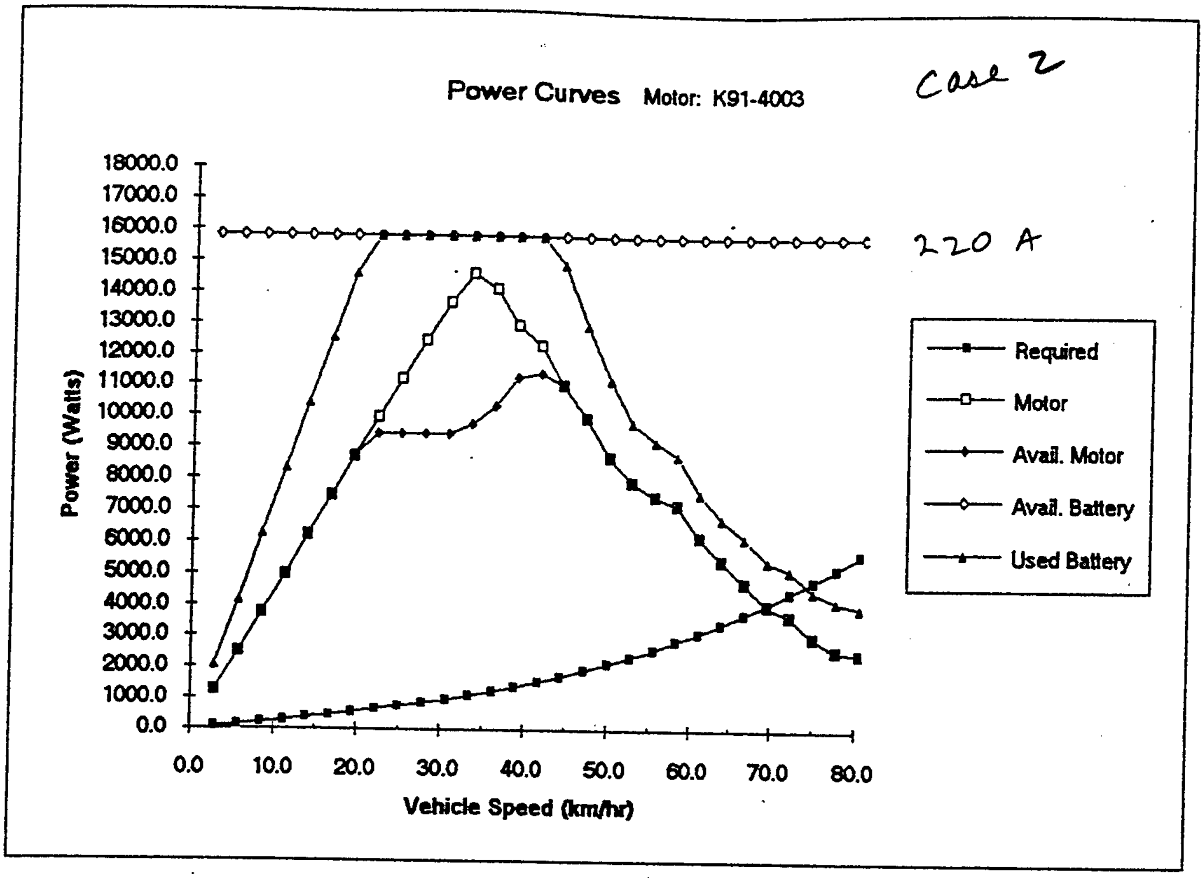
A3-4

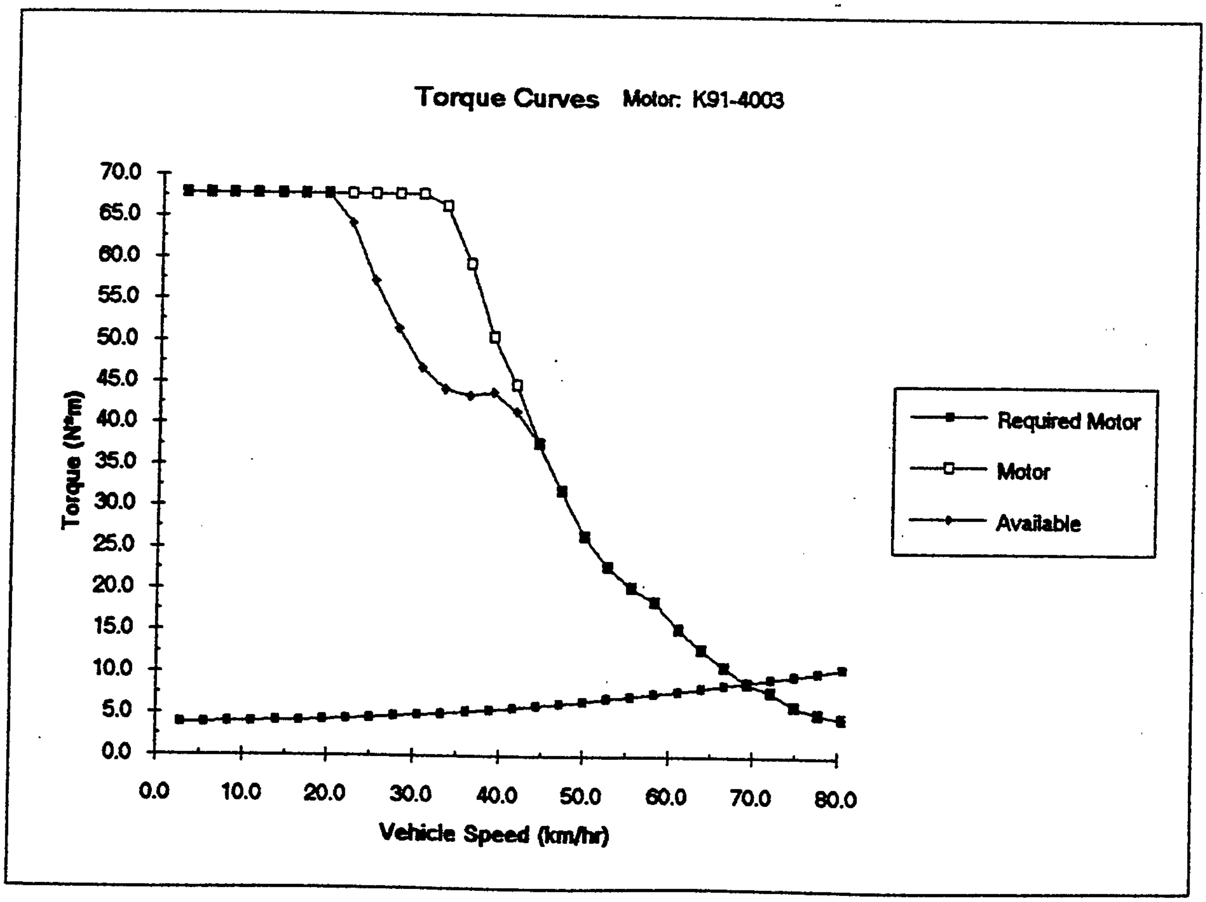
3850	4025	4200	4375	4550	4725	4900	5075	5250	5425	
15.3	12.9	10.8	8.8	7.8	6.1	5.1	4.7	3.7	3.1	
85%	84%	80%	77%	75%	70%	65%	65%	60%	59%	
403.2	421.5	439.8	458.1	476.5	494.8	513.1	531.5	549.8	568.1	
6168.5	5437.3	4750.1	4031.7	3716.5	3018.3	2616.9	2497.8	2034.2	1761.1	
5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	
73.3	76.6	80.0	83.3	86.6	90.0	93.3	96.6	100.0	103.3	
700.0	731.8	763.6	795.5	827.3	859.1	890.9	922.7	954.5	986.4	
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	
72.2	75.5	78.7	82.0	85.3	88.6	91.9	95.1	98.4	101.7	
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	
0	0	0	0	0	0	0	0	0	0	
108.7	118.8	129.4	140.4	151.8	163.7	176.1	188.9	202.1	215.8	
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
400	400	400	400	400	400	400	400	400	400	
90	90	90	90	90	90	90	90	90	90	
490	490	490	490	490	490	490	490	490	490	
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	67.3	
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	
4.0	4.2	4.4	4.6	4.8	4.9	5.1	5.3	5.5	5.7	
180.0	190.3	201.1	212.2	223.9	236.0	248.5	261.5	274.9	288.8	
3609.3	3989.0	4397.4	4835.5	5304.6	5806.0	6341.0	6910.6	7516.2	8158.9	
49.2	52.1	55.0	58.0	61.2	64.5	68.0	71.5	75.2	79.0	
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	
4148.6	4585.1	5054.4	5558.0	6097.3	6673.6	7288.5	7943.2	8639.3	9378.1	
10.3	10.9	11.5	12.1	12.8	13.5	14.2	14.9	15.7	16.5	Readtorque
72	72	72	72	72	72	72	72	72	72	
220	220	220	220	220	220	220	220	220	220	
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	
7559.5	6742.7	6185.0	5454.1	5161.8	4491.5	4193.8	4002.9	3531.6	3109.3	
105.0	93.6	85.9	75.8	71.7	62.4	58.2	55.6	49.0	43.2	
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	
7257.1	6473.0	5937.6	5236.0	4955.3	4311.8	4026.1	3842.8	3390.3	2985.0	
100.8	89.9	82.5	72.7	68.8	59.9	55.9	53.4	47.1	41.5	
6168.5	5437.3	4750.1	4031.7	3716.5	3018.3	2616.9	2497.8	2034.2	1761.1	
15.3	12.9	10.8	8.8	7.8	6.1	5.1	4.7	3.7	3.1	Available motor Torqu
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
73.2	61.7	51.7	42.1	37.3	29.2	24.4	22.5	17.7	14.8	
267.7	225.7	189.0	154.0	136.5	106.7	89.2	82.2	64.7	54.2	
0.16	0.07	-0.02	-0.11	-0.16	-0.24	-0.30	-0.33	-0.39	-0.44	
25.6	39.5	-1.1	-9.5	-15.2	-19.0	-22.0	-24.8	-27.1	-28.2	

max speed

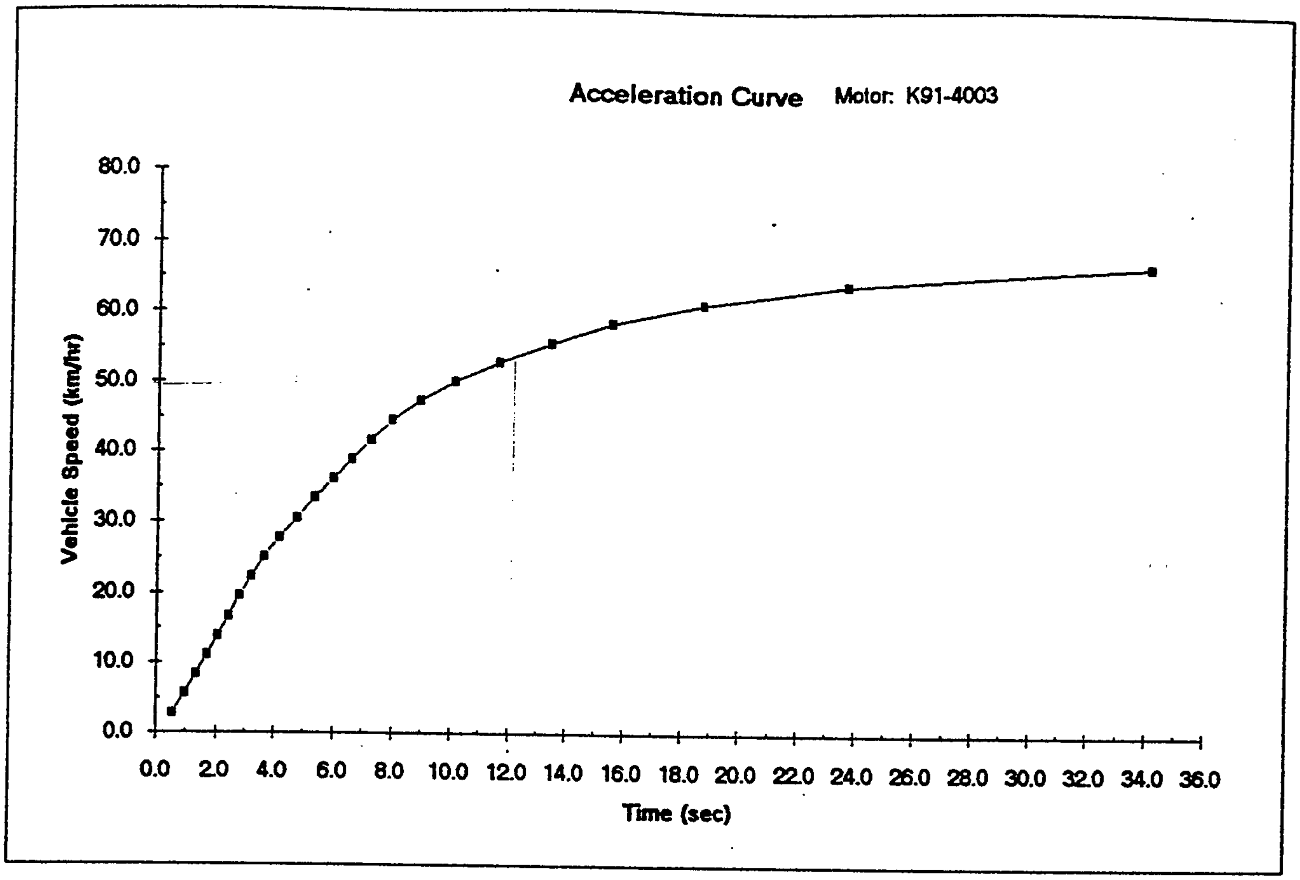
A3-5

6.5 180 1kg load





A3-6


Acceleration Curve Motor: K91-4003
Vehicle Speed (km/hr)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0
Time (sec)

A3-7

Print Date: 2-8-95

Pacific EV Vehicle Performance Model

Motor: K91-4003

Motor Speed (rpm)	175	350	525	700	875	1050	1225	1400	1575
Max Motor Torque (N*m)	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8
Eff. at Max Power (%)	62%	62%	62%	62%	62%	62%	62%	62%	62%
Motor Speed (rad/s)	18.3	36.7	55.0	73.3	91.6	110.0	128.3	146.6	164.9
Max Motor Power (W)	1242.5	2485.0	3727.5	4970.0	6212.5	7455.0	8697.5	9940.0	11182.5
Drive Ratio	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wheel Speed (rad/s)	2.8	5.6	8.5	11.3	14.1	16.9	19.7	22.6	25.4
Wheel Speed (rpm)	26.9	53.8	80.8	107.7	134.6	161.5	188.5	215.4	242.3
Tire Diameter (m)	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
Vehicle Speed (km/hr)	2.8	5.6	8.3	11.1	13.9	16.7	19.4	22.2	25.0
Drag Coeff. Cd	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Frontal Area (m^2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Air Density (kg/m^3)	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
Head Wind (km/hr)	0	0	0	0	0	0	0	0	0
F wind (N)	0.2	0.6	1.4	2.6	4.0	5.8	7.9	10.3	13.0
Percent Grade	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vehicle Mass (kg)	400	400	400	400	400	400	400	400	400
Passenger + Cargo Mass (kg)	180	180	180	180	180	180	180	180	180
Total Mass (kg)	580	580	580	580	580	580	580	580	580
Crr1 (Rolling Resistance)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
F grade (N)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F roll (N)	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
Crr2 (Wheel Windage)	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
F windage (N)	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4
F total (N)	80.0	80.6	81.6	82.8	84.5	86.4	88.6	91.2	94.1
Wheel Power (W)	61.7	124.3	188.7	255.5	325.6	399.6	478.3	562.5	652.9
Wheel Torque (N*m)	21.9	22.0	22.3	22.7	23.1	23.6	24.2	24.9	25.7
Mechanical Eff.	87%	87%	87%	87%	87%	87%	87%	87%	87%
Required Motor Power (W)	70.9	142.9	216.9	293.7	374.3	459.3	549.8	646.6	750.4
Required Motor Torque (N*m)	3.9	3.9	3.9	4.0	4.1	4.2	4.3	4.4	4.5
Nom. Batt. Voltage (V)	72	72	72	72	72	72	72	72	72
Max Batt. Current (A)	220	220	220	220	220	220	220	220	220
Max Batt Power (W)	15840	15840	15840	15840	15840	15840	15840	15840	15840
Amp. Power (W)	2087.5	4175.1	6262.6	8350.1	10437.7	12525.2	14612.7	15840.0	15840.0
Amp. Current (A)	29.0	58.0	87.0	116.0	145.0	174.0	203.0	220.0	220.0
Amplifier Eff. (from Graph?)	96%	96%	96%	96%	96%	96%	96%	96%	96%
Electrical Power (W)	2004.0	4008.1	6012.1	8016.1	10020.2	12024.2	14028.2	15206.4	15206.4
Motor Current (A)	27.8	55.7	83.5	111.3	139.2	167.0	194.8	211.2	211.2
Max Avail. Motor Power (W)	1242.5	2485.0	3727.5	4970.0	6212.5	7455.0	8697.5	9428.0	9428.0
Max Avail. Motor Torque (N*m)	67.8	67.8	67.8	67.8	67.8	67.8	67.8	64.3	57.2
km (Rotational Inertia)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Max. Wheel Torque (N*m)	383.4	383.4	383.4	383.4	383.4	383.4	383.4	363.7	323.3
Max. Wheel Force (N)	1401.9	1401.9	1401.9	1401.9	1401.9	1401.9	1401.9	1329.6	1181.9
Accel. (m/s^2)	2.07	2.07	2.07	2.07	2.06	2.06	2.06	1.94	1.71
Accel Time (s)	0.6	0.9	1.3	1.7	2.0	2.4	2.8	3.2	3.6

A3-3

1750	1925	2100	2275	2450	2625	2800	2975	3150	3325	3500	3675
67.8	67.8	66.4	59.3	50.5	44.7	37.6	31.9	26.4	22.7	20.3	18.6
62%	62%	64%	68%	74%	75%	77%	80%	81%	84%	84%	85%
183.3	201.6	219.9	238.2	256.6	274.9	293.2	311.5	329.9	348.2	366.5	384.8
12425.0	13667.5	14602.1	14127.5	12956.4	12287.5	11024.9	9938.2	8708.5	7904.0	7440.3	7158.1

6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
28.2	31.0	33.8	36.7	39.5	42.3	45.1	47.9	50.7	53.6	56.4	59.2
269.2	296.2	323.1	350.0	376.9	403.8	430.8	457.7	484.6	511.5	538.5	565.4
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
27.8	30.5	33.3	36.1	38.9	41.6	44.4	47.2	50.0	52.7	55.5	58.3

0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0	0	0
16.1	19.5	23.2	27.2	31.5	36.2	41.2	46.5	52.1	58.1	64.3	70.9
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	400	400	400	400	400	400	400	400	400	400	400
180	180	180	180	180	180	180	180	180	180	180	180
580	580	580	580	580	580	580	580	580	580	580	580
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
1.5	1.7	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.3
97.3	100.8	104.7	108.8	113.3	118.2	123.3	128.8	134.5	140.7	147.1	153.8
750.2	855.1	968.5	1091.1	1223.6	1366.7	1521.2	1687.9	1867.5	2060.7	2268.2	2490.9
26.6	27.6	28.6	29.8	31.0	32.3	33.7	35.2	36.8	38.5	40.2	42.1
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
862.3	982.9	1113.3	1254.1	1406.4	1570.9	1748.6	1940.1	2146.5	2368.6	2607.1	2863.1
4.7	4.9	5.1	5.3	5.5	5.7	6.0	6.2	6.5	6.8	7.1	7.4

72	72	72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
15840.0	15840.0	15840.0	15840.0	15840.0	15840.0	14914.6	12940.3	11199.2	9801.6	9226.6	8772.2
220.0	220.0	220.0	220.0	220.0	220.0	207.1	179.7	155.5	136.1	128.1	121.8
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
15206.4	15206.4	15206.4	15206.4	15206.4	15206.4	14318.0	12422.7	10751.2	9409.5	8857.5	8421.3
211.2	211.2	211.2	211.2	211.2	211.2	198.9	172.5	149.3	130.7	123.0	117.0
9428.0	9428.0	9732.1	10340.4	11252.7	11404.8	11024.9	9938.2	8708.5	7904.0	7440.3	7158.1
51.4	46.8	44.3	43.4	43.9	41.5	37.6	31.9	26.4	22.7	20.3	18.6

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
290.9	264.5	250.3	245.4	248.0	234.6	212.6	180.4	149.3	128.4	114.8	105.2
1063.7	967.0	915.0	897.4	906.9	857.8	777.4	659.6	545.9	469.4	419.7	384.6
1.51	1.36	1.27	1.24	1.24	1.16	1.03	0.83	0.64	0.52	0.43	0.36
4.2	4.7	5.3	6.0	6.6	7.2	8.0	8.9	10.1	11.6	13.4	15.5

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3850	4025	4200	4375	4550	4725	4900	5075	5250	5425	
15.3	12.9	10.8	8.8	7.8	6.1	5.1	4.7	3.7	3.1	
85%	84%	80%	77%	75%	70%	65%	65%	60%	59%	
403.2	421.5	439.8	458.1	476.5	494.8	513.1	531.5	549.8	568.1	
6168.5	5437.3	4750.1	4031.7	3716.5	3018.3	2616.9	2497.8	2034.2	1761.1	

6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	
62.0	64.8	67.7	70.5	73.3	76.1	78.9	81.8	84.6	87.4	
592.3	619.2	646.2	673.1	700.0	726.9	753.8	780.8	807.7	834.6	
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	
61.1	63.8	66.6	69.4	72.2	75.0	77.7	80.5	83.3	86.1	
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	
0	0	0	0	0	0	0	0	0	0	
77.8	85.1	92.6	100.5	108.7	117.2	126.1	135.2	144.7	154.5	
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
400	400	400	400	400	400	400	400	400	400	
180	180	180	180	180	180	180	180	180	180	
580	580	580	580	580	580	580	580	580	580	
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	
3.4	3.6	3.7	3.9	4.0	4.2	4.3	4.5	4.6	4.8	
160.9	168.3	176.0	184.0	192.4	201.1	210.1	219.4	229.0	239.0	
2729.4	2984.6	3257.1	3547.7	3857.1	4186.1	4535.5	4905.9	5298.1	5712.9	
44.0	46.0	48.1	50.3	52.6	55.0	57.5	60.0	62.6	65.4	
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	
3137.3	3430.6	3743.8	4077.8	4433.5	4811.6	5213.2	5638.9	6089.8	6566.5	
7.8	8.1	8.5	8.9	9.3	9.7	10.2	10.6	11.1	11.6	Reqd Torque

72	72	72	72	72	72	72	72	72	72	
220	220	220	220	220	220	220	220	220	220	
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	
7559.5	6742.7	6185.0	5454.1	5161.8	4491.5	4193.8	4002.9	3531.6	3109.3	
105.0	93.6	85.9	75.8	71.7	62.4	58.2	55.6	49.0	43.2	
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	
7257.1	6473.0	5937.6	5236.0	4955.3	4311.8	4026.1	3842.8	3390.3	2985.0	
100.8	89.9	82.5	72.7	68.8	59.9	55.9	53.4	47.1	41.5	
6168.5	5437.3	4750.1	4031.7	3716.5	3018.3	2616.9	2497.8	2034.2	1761.1	
15.3	12.9	10.8	8.8	7.8	6.1	5.1	4.7	3.7	3.1	available torque

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
86.5	72.9	61.1	49.8	44.1	34.5	28.8	26.6	20.9	17.5	
316.3	266.7	223.3	182.0	161.3	126.1	105.4	97.2	76.5	64.1	
0.24	0.15	0.07	0.00	-0.05	-0.12	-0.16	-0.19	-0.24	-0.27	
18.7	23.7	34.1	-202.4	-218.2	-224.8	-229.5	-233.5	-236.7	-238.1	

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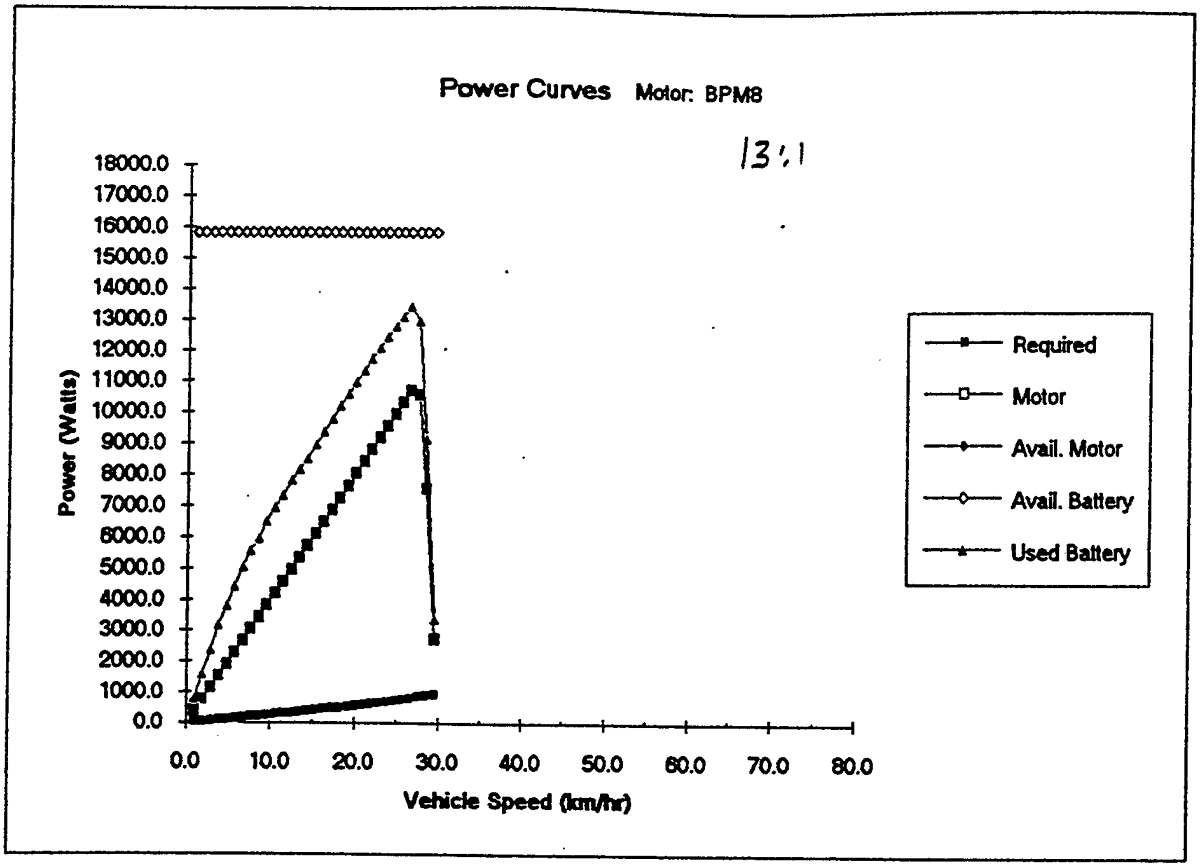
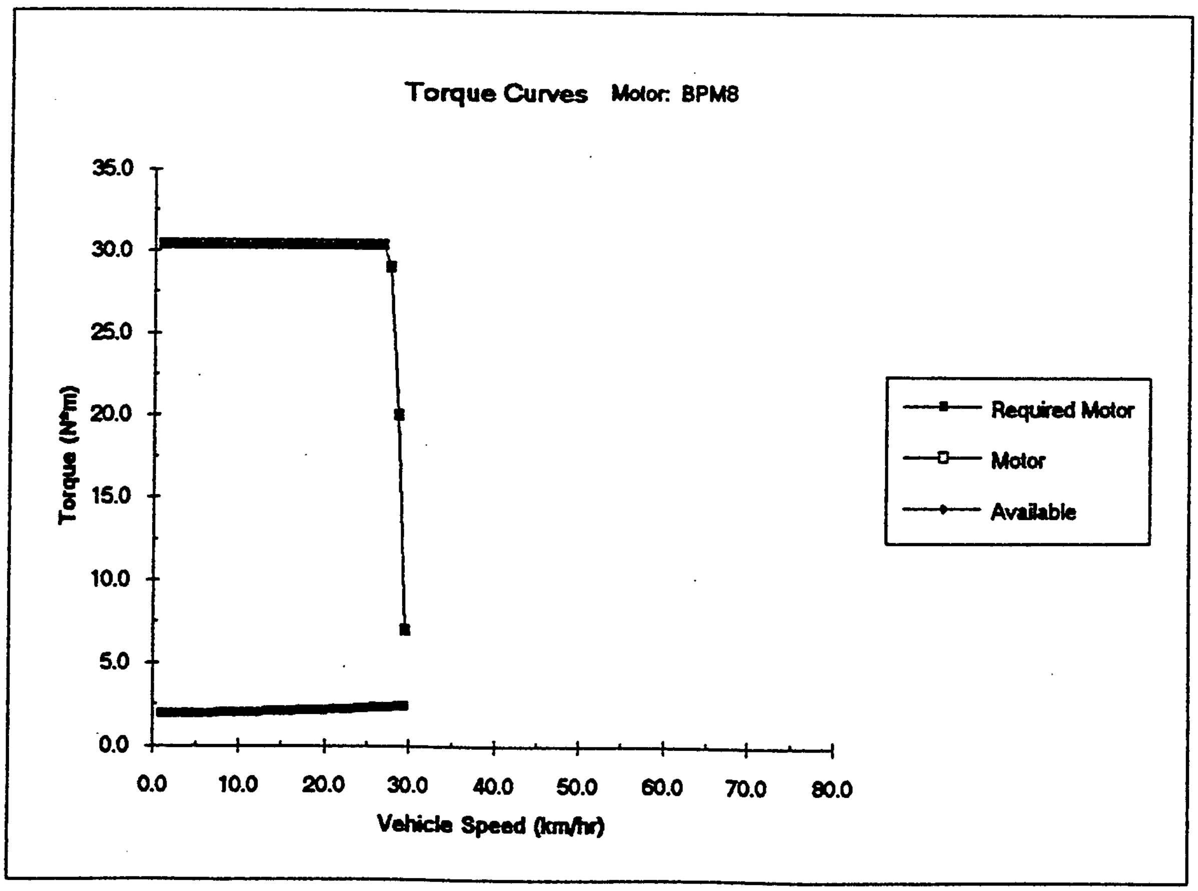
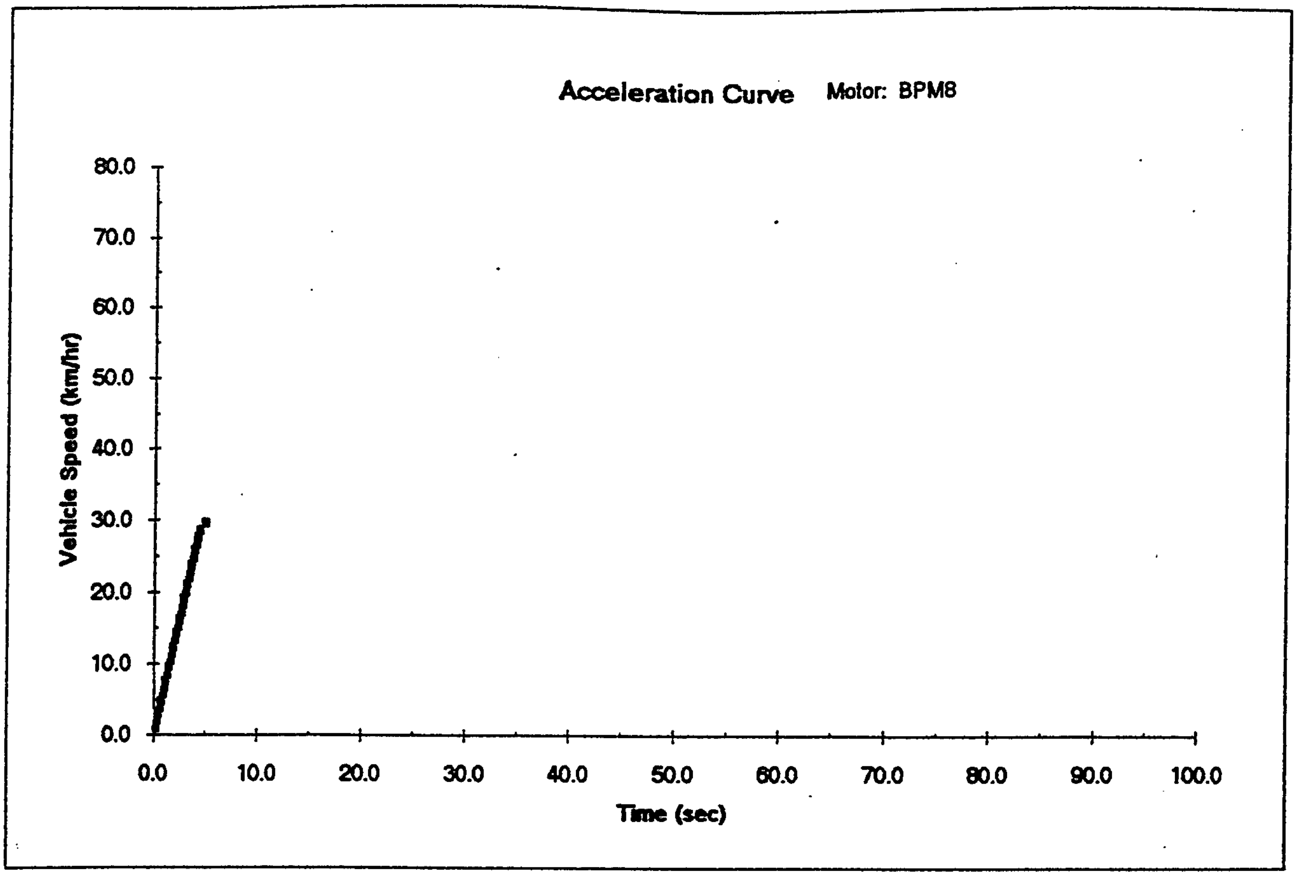
*

13:1


Power Curves Motor: BPM8
13:1
18000.0
17000.0
16000.0
15000.0
14000.0
13000.0
12000.0
11000.0
10000.0
9000.0
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
Power (Watts)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Vehicle Speed (km/hr)
Required
Motor
Avail. Motor
Avail. Battery
Used Battery


Torque Curves Motor: BPM8
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Torque (N*m)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Vehicle Speed (km/hr)
Required Motor
Motor
Available

A3-11


Acceleration Curve
Motor: BPM8
Vehicle Speed (km/hr)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Time (sec)

A3-12

Pacific EV Vehicle Performance Model   Motor: BPM8

Motor Speed (rpm)	120	240	360	480	600	720	840	960	1080
Max Motor Torque (N*m)	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4
Eff. at Max Power (%)	50%	50%	50%	50%	52%	54%	55%	57%	60%
Motor Speed (rad/s)	12.6	25.1	37.7	50.3	62.8	75.4	88.0	100.5	113.1
Max Motor Power (W)	382.0	764.0	1146.1	1528.1	1910.1	2292.1	2674.1	3056.1	3438.2

Drive Ratio	13	13	13	13	13	13	13	13	13
Wheel Speed (rad/s)	1.0	1.9	2.9	3.9	4.8	5.8	6.8	7.7	8.7
Wheel Speed (rpm)	9.2	18.5	27.7	36.9	46.2	55.4	64.6	73.8	83.1
Tire Diameter (m)	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
Vehicle Speed (km/hr)	1.0	1.9	2.9	3.8	4.8	5.7	6.7	7.6	8.6
Drag Coeff. Cd	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Frontal Area (m^2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Air Density (kg/m^3)	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
Head Wind (km/hr)	0	0	0	0	0	0	0	0	0
F wind (N)	0.0	0.1	0.2	0.3	0.5	0.7	0.9	1.2	1.5
Percent Grade	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vehicle Mass (kg)	400	400	400	400	400	400	400	400	400
Passenger + Cargo Mass (kg)	180	180	180	180	180	180	180	180	180
Total Mass (kg)	580	580	580	580	580	580	580	580	580
Crr1 (Rolling Resistance)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
F grade (N)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F roll (N)	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
Crr2 (Wheel Windage)	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
F windage (N)	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
F total (N)	79.7	79.8	80.0	80.2	80.4	80.7	81.0	81.3	81.7
Wheel Power (W)	21.1	42.2	63.4	84.8	106.3	127.9	149.8	171.9	194.3
Wheel Torque (N*m)	21.8	21.8	21.9	21.9	22.0	22.1	22.1	22.2	22.3
Mechanical Eff.	87%	87%	87%	87%	87%	87%	87%	87%	87%
Required Motor Power (W)	24.2	48.5	72.9	97.5	122.2	147.1	172.2	197.6	223.4
Required Motor Torque (N*m)	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0

Nom. Batt. Voltage (V)	72	72	72	72	72	72	72	72	72
Max Batt. Current (A)	220	220	220	220	220	220	220	220	220
Max Batt Power (W)	15840	15840	15840	15840	15840	15840	15840	15840	15840
Amp. Power (W)	795.9	1591.7	2387.6	3183.5	3826.3	4421.5	5064.6	5585.0	5969.0
Amp. Current (A)	11.1	22.1	33.2	44.2	53.1	61.4	70.3	77.6	82.9
Amplifier Eff. (from Graph?)	96%	96%	96%	96%	96%	96%	96%	96%	96%
Electrical Power (W)	764.0	1528.1	2292.1	3056.1	3673.2	4244.6	4862.0	5361.6	5730.3
Motor Current (A)	10.6	21.2	31.8	42.4	51.0	59.0	67.5	74.5	79.6
Max Avail. Motor Power (W)	382.0	764.0	1146.1	1528.1	1910.1	2292.1	2674.1	3056.1	3438.2
Max Avail. Motor Torque (N*m)	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4

km (Rotational Inertia)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Max. Wheel Torque (N*m)	343.8	343.8	343.8	343.8	343.8	343.8	343.8	343.8	343.8
Max. Wheel Force (N)	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1
Accel. (m/s^2)	1.85	1.85	1.85	1.84	1.84	1.84	1.84	1.84	1.84
Accel Time (s)	0.2	0.4	0.5	0.6	0.8	0.9	1.1	1.2	1.4

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1200	1320	1440	1560	1680	1800	1920	2040	2160	2280	2400	2520
30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4
61%	63%	65%	66%	68%	70%	71%	72%	73%	74%	75%	76%
125.7	138.2	150.8	163.4	175.9	188.5	201.1	213.6	226.2	238.8	251.3	263.9
3820.2	4202.2	4584.2	4966.2	5348.2	5730.3	6112.3	6494.3	6876.3	7258.3	7640.3	8022.4

13	13	13	13	13	13	13	13	13	13	13	13
9.7	10.6	11.6	12.6	13.5	14.5	15.5	16.4	17.4	18.4	19.3	20.3
92.3	101.5	110.8	120.0	129.2	138.5	147.7	156.9	166.2	175.4	184.6	193.8
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
9.5	10.5	11.4	12.4	13.3	14.3	15.2	16.2	17.1	18.1	19.0	20.0

0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0	0	0
1.9	2.3	2.7	3.2	3.7	4.3	4.8	5.5	6.1	6.8	7.6	8.3
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	400	400	400	400	400	400	400	400	400	400	400
180	180	180	180	180	180	180	180	180	180	180	180
580	580	580	580	580	580	580	580	580	580	580	580
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.1
82.1	82.5	83.0	83.5	84.1	84.7	85.3	86.0	86.7	87.5	88.3	89.1
217.0	240.0	263.4	287.1	311.3	335.9	361.0	386.6	412.8	439.5	466.8	494.7
22.4	22.6	22.7	22.8	23.0	23.2	23.3	23.5	23.7	23.9	24.1	24.4
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
249.4	275.9	302.7	330.0	357.8	386.1	415.0	444.4	474.4	505.1	536.5	568.6
2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.2

72	72	72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
6523.5	6948.1	7346.5	7838.1	8192.8	8527.2	8967.5	9395.7	9812.1	10217.2	10611.6	10995.6
90.6	96.5	102.0	108.9	113.8	118.4	124.5	130.5	136.3	141.9	147.4	152.7
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
6262.6	6670.1	7052.6	7524.6	7865.1	8186.1	8608.8	9019.9	9419.6	9808.6	10187.1	10555.7
87.0	92.6	98.0	104.5	109.2	113.7	119.6	125.3	130.8	136.2	141.5	146.6
3820.2	4202.2	4584.2	4966.2	5348.2	5730.3	6112.3	6494.3	6876.3	7258.3	7640.3	8022.4
30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
343.8	343.8	343.8	343.8	343.8	343.8	343.8	343.8	343.8	343.8	343.8	343.8
1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1
1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.83	1.83	1.83	1.83
1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.5	2.7	2.8	2.9	3.1

A3-14

2640	2760	2880	3000	3120	3240	3360	3480	3600	3720
30.4	30.4	30.4	30.4	30.4	30.4	30.4	29	20	7
77%	78%	79%	80%	81%	82%	83%	85%	86%	84%
276.5	289.0	301.6	314.2	326.7	339.3	351.9	364.4	377.0	389.6
8404.4	8786.4	9168.4	9550.4	9932.5	10314.5	10696.5	10568.3	7539.8	2726.9

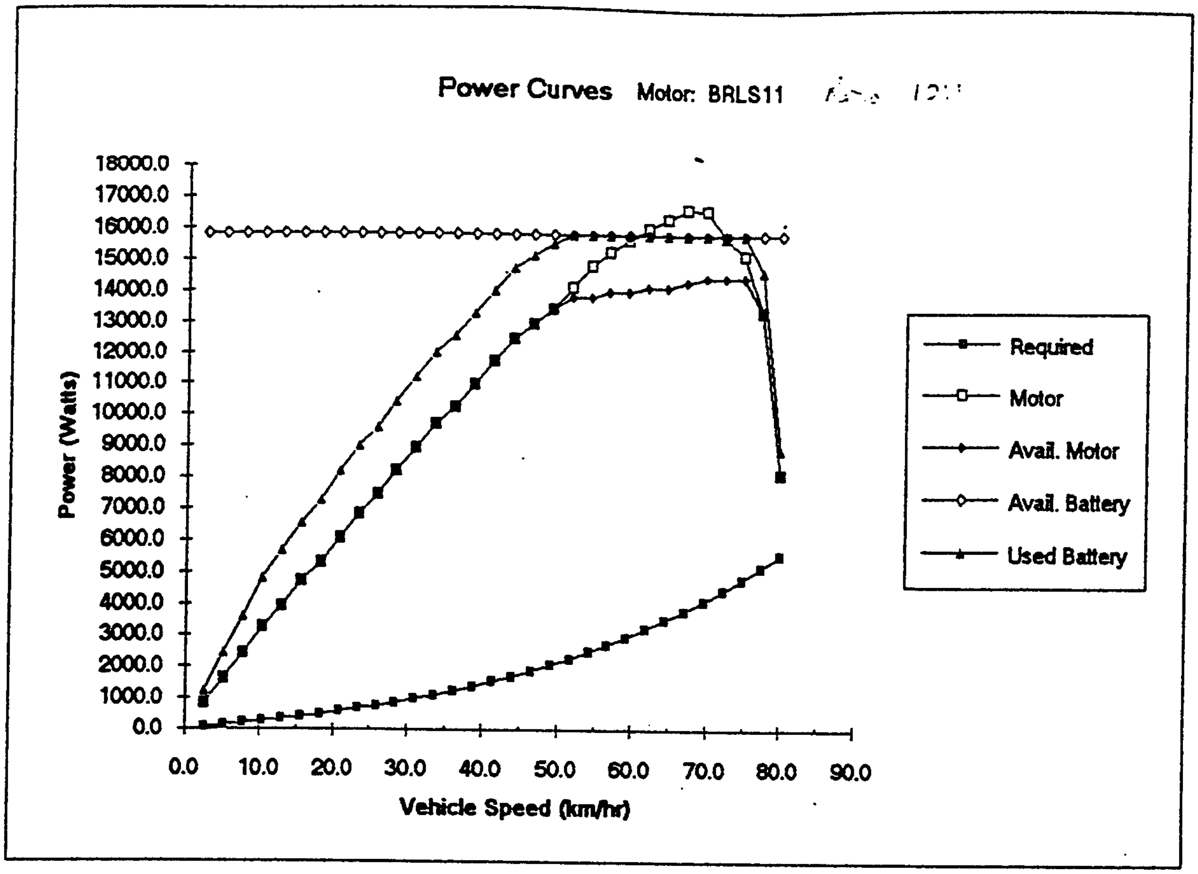
13	13	13	13	13	13	13	13	13	13
21.3	22.2	23.2	24.2	25.1	26.1	27.1	28.0	29.0	30.0
203.1	212.3	221.5	230.8	240.0	249.2	258.5	267.7	276.9	286.2
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
20.9	21.9	22.8	23.8	24.7	25.7	26.6	27.6	28.6	29.5

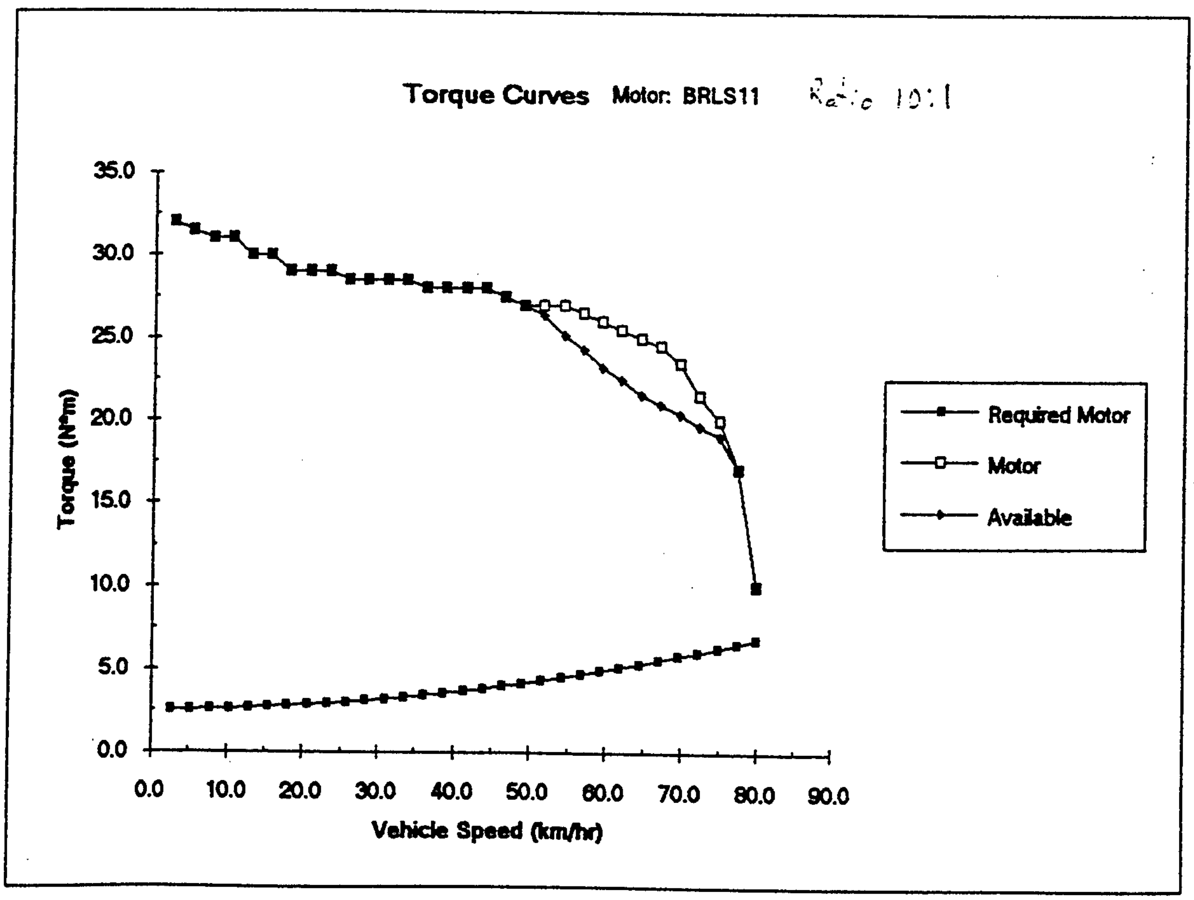
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0
9.1	10.0	10.9	11.8	12.8	13.8	14.8	15.9	17.0	18.2
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	400	400	400	400	400	400	400	400	400
180	180	180	180	180	180	180	180	180	180
580	580	580	580	580	580	580	580	580	580
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6
90.0	90.9	91.8	92.8	93.8	94.9	96.0	97.1	98.3	99.5
523.3	552.6	582.6	613.3	644.9	677.2	710.4	744.4	779.4	815.2
24.6	24.9	25.1	25.4	25.7	25.9	26.2	26.6	26.9	27.2
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
601.5	635.2	669.7	705.0	741.2	778.4	816.5	855.6	895.8	937.0
2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.4	2.4

72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
11369.6	11734.0	12089.2	12435.5	12773.2	13102.7	13424.3	12951.4	9132.5	3381.6
157.9	163.0	167.9	172.7	177.4	182.0	186.4	179.9	126.8	47.0
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
10914.8	11264.6	11605.6	11938.0	12262.3	12578.6	12887.3	12433.3	8767.2	3246.3
151.6	156.5	161.2	165.8	170.3	174.7	179.0	172.7	121.8	45.1
8404.4	8786.4	9168.4	9550.4	9932.5	10314.5	10696.5	10568.3	7539.8	2726.9
30.4	30.4	30.4	30.4	30.4	30.4	30.4	29.0	20.0	7.0

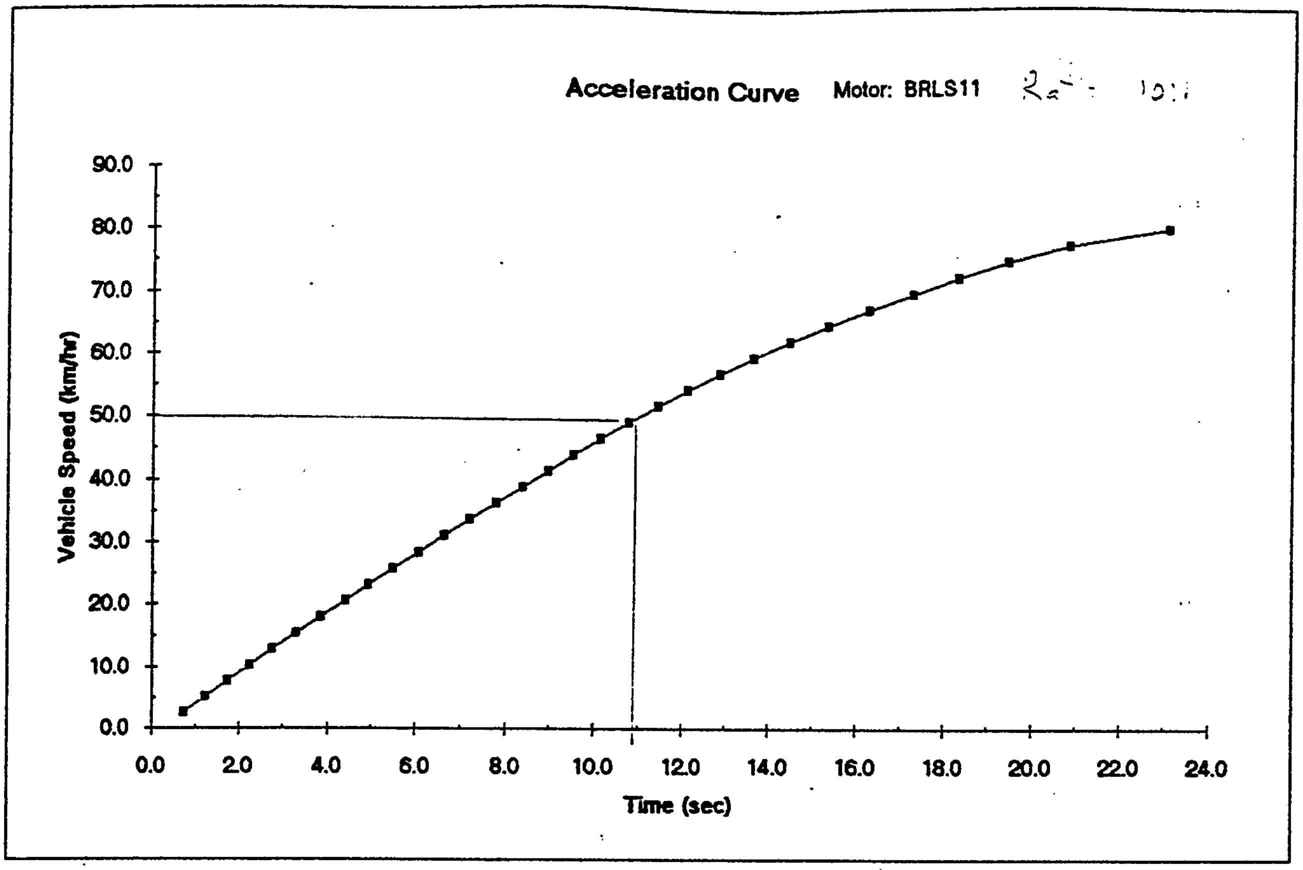
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
343.8	343.8	343.8	343.8	343.8	343.8	343.8	328.0	226.2	79.2
1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1257.1	1199.2	827.1	289.5
1.83	1.83	1.83	1.82	1.82	1.82	1.82	1.73	1.14	0.30
3.2	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.5	4.9

A3-15


Power Curves Motor: BRLS11
Power (Watts)
Vehicle Speed (km/hr)
Required
Motor
Avail. Motor
Avail. Battery
Used Battery


Torque Curves Motor: BRLS11 Ratio 10:1
Torque (N*m)
Vehicle Speed (km/hr)
Required Motor
Motor
Available

A3-16


Acceleration Curve
Motor: BRLS11
Vehicle Speed (km/hr)
Time (sec)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0

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Print Date: 2-9-95

Pacific EV Vehicle Performance Model Motor: BRLS11

Motor Speed (rpm)	250	500	750	1000	1250	1500	1750	2000	2250
Max Motor Torque (N*m)	32	31.5	31	31	30	30	29	29	29
Eff. at Max Power (%)	70%	70%	70%	70%	72%	75%	76%	77%	79%
Motor Speed (rad/s)	26.2	52.4	78.5	104.7	130.9	157.1	183.3	209.4	235.6
Max Motor Power (W)	837.8	1649.3	2434.7	3246.3	3927.0	4712.4	5314.5	6073.7	6833.0
Drive Ratio	10	10	10	10	10	10	10	10	10
Wheel Speed (rad/s)	2.6	5.2	7.9	10.5	13.1	15.7	18.3	20.9	23.6
Wheel Speed (rpm)	25.0	50.0	75.0	100.0	125.0	150.0	175.0	200.0	225.0
Tire Diameter (m)	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
Vehicle Speed (km/hr)	2.6	5.2	7.7	10.3	12.9	15.5	18.0	20.6	23.2
Drag Coeff. Cd	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Frontal Area (m^2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Air Density (kg/m^3)	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
Head Wind (km/hr)	0	0	0	0	0	0	0	0	0
F wind (N)	0.1	0.6	1.2	2.2	3.5	5.0	6.8	8.9	11.2
Percent Grade	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vehicle Mass (kg)	400	400	400	400	400	400	400	400	400
Passenger + Cargo Mass (kg)	180	180	180	180	180	180	180	180	180
Total Mass (kg)	580	580	580	580	580	580	580	580	580
Crr1 (Rolling Resistance)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
F grade (N)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F roll (N)	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
Crr2 (Wheel Windage)	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
F windage (N)	0.1	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3
F total (N)	79.9	80.5	81.3	82.5	83.8	85.5	87.5	89.7	92.2
Wheel Power (W)	57.2	115.3	174.7	236.1	300.2	367.4	438.4	513.7	594.0
Wheel Torque (N*m)	21.9	22.0	22.2	22.6	22.9	23.4	23.9	24.5	25.2
Mechanical Eff.	87%	87%	87%	87%	87%	87%	87%	87%	87%
Required Motor Power (W)	65.8	132.5	200.8	271.4	345.0	422.3	503.9	590.5	682.8
Required Motor Torque (N*m)	2.5	2.5	2.6	2.6	2.6	2.7	2.7	2.8	2.9
Nom. Batt. Voltage (V)	72	72	72	72	72	72	72	72	72
Max Batt. Current (A)	220	220	220	220	220	220	220	220	220
Max Batt Power (W)	15840	15840	15840	15840	15840	15840	15840	15840	15840
Amp. Power (W)	1246.7	2454.4	3623.1	4830.8	5681.4	6545.0	7284.2	8216.6	9009.7
Amp. Current (A)	17.3	34.1	50.3	67.1	78.9	90.9	101.2	114.1	125.1
Amplifier Eff. (from Graph?)	96%	96%	96%	96%	96%	96%	96%	96%	96%
Electrical Power (W)	1196.8	2356.2	3478.2	4637.6	5454.1	6283.2	6992.8	7888.0	8649.3
Motor Current (A)	16.6	32.7	48.3	64.4	75.8	87.3	97.1	109.6	120.1
Max Avail. Motor Power (W)	837.8	1649.3	2434.7	3246.3	3927.0	4712.4	5314.5	6073.7	6833.0
Max Avail. Motor Torque (N*m)	32.0	31.5	31.0	31.0	30.0	30.0	29.0	29.0	29.0
km (Rotational Inertia)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Max. Wheel Torque (N*m)	278.4	274.1	269.7	269.7	261.0	261.0	252.3	252.3	252.3
Max. Wheel Force (N)	1017.9	1002.0	986.1	986.1	954.3	954.3	922.5	922.5	922.5
Accel. (m/s^2)	1.47	1.44	1.42	1.42	1.36	1.36	1.31	1.31	1.30
Accel Time (s)	0.7	1.2	1.7	2.2	2.8	3.3	3.8	4.4	4.9

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2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	5250
28.5	28.5	28.5	28.5	28	28	28	28	27.5	27	27	27
81%	82%	83%	84%	85%	86%	87%	88%	89%	90%	91%	91%
261.8	288.0	314.2	340.3	366.5	392.7	418.9	445.1	471.2	497.4	523.6	549.8
7461.3	8207.4	8953.5	9699.7	10262.5	10995.6	11728.6	12461.6	12959.1	13430.3	14137.2	14844.0

10	10	10	10	10	10	10	10	10	10	10	10
26.2	28.8	31.4	34.0	36.7	39.3	41.9	44.5	47.1	49.7	52.4	55.0
250.0	275.0	300.0	325.0	350.0	375.0	400.0	425.0	450.0	475.0	500.0	525.0
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
25.8	28.4	30.9	33.5	36.1	38.7	41.2	43.8	46.4	49.0	51.6	54.1

0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0	0	0
13.9	16.8	20.0	23.4	27.2	31.2	35.5	40.1	44.9	50.1	55.5	61.1
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	400	400	400	400	400	400	400	400	400	400	400
180	180	180	180	180	180	180	180	180	180	180	180
580	580	580	580	580	580	580	580	580	580	580	580
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
1.4	1.6	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.7	2.9	3.0
95.0	98.0	101.3	105.0	108.8	113.0	117.5	122.2	127.2	132.4	138.0	143.8
679.9	772.0	870.8	977.0	1091.1	1213.8	1345.6	1487.1	1639.0	1801.8	1976.1	2162.6
26.0	26.8	27.7	28.7	29.8	30.9	32.1	33.4	34.8	36.2	37.7	39.3
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
781.5	887.4	1000.9	1123.0	1254.1	1395.1	1546.6	1709.3	1883.9	2071.0	2271.4	2485.7
3.0	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4.0	4.2	4.3	4.5

72	72	72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
9595.3	10426.1	11236.9	12028.3	12576.6	13318.3	14042.9	14751.0	15167.4	15544.3	15840.0	15840.0
133.3	144.8	156.1	167.1	174.7	185.0	195.0	204.9	210.7	215.9	220.0	220.0
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
9211.5	10009.0	10787.4	11547.2	12073.6	12785.5	13481.2	14161.0	14560.7	14922.6	15206.4	15206.4
127.9	139.0	149.8	160.4	167.7	177.6	187.2	196.7	202.2	207.3	211.2	211.2
7461.3	8207.4	8953.5	9699.7	10262.5	10995.6	11728.6	12461.6	12959.1	13430.3	13837.8	13837.8
28.5	28.5	28.5	28.5	28.0	28.0	28.0	28.0	27.5	27.0	26.4	25.2

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
248.0	248.0	248.0	248.0	243.6	243.6	243.6	243.6	239.3	234.9	228.9	219.0
906.6	906.6	906.6	906.6	890.7	890.7	890.7	890.7	874.8	858.9	840.7	800.6
1.27	1.27	1.26	1.26	1.23	1.22	1.21	1.20	1.17	1.14	1.10	1.03
5.5	6.1	6.6	7.2	7.8	8.4	9.0	9.6	10.2	10.8	11.4	12.1

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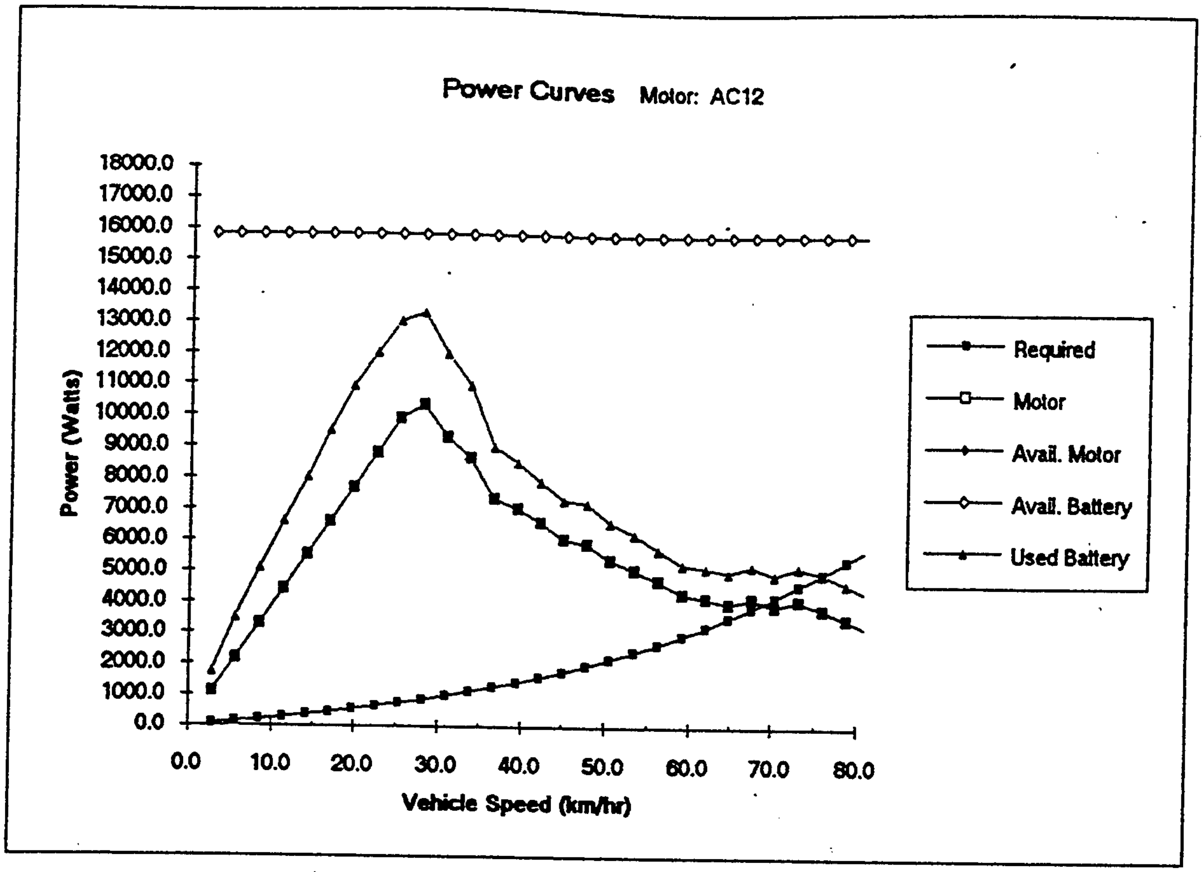
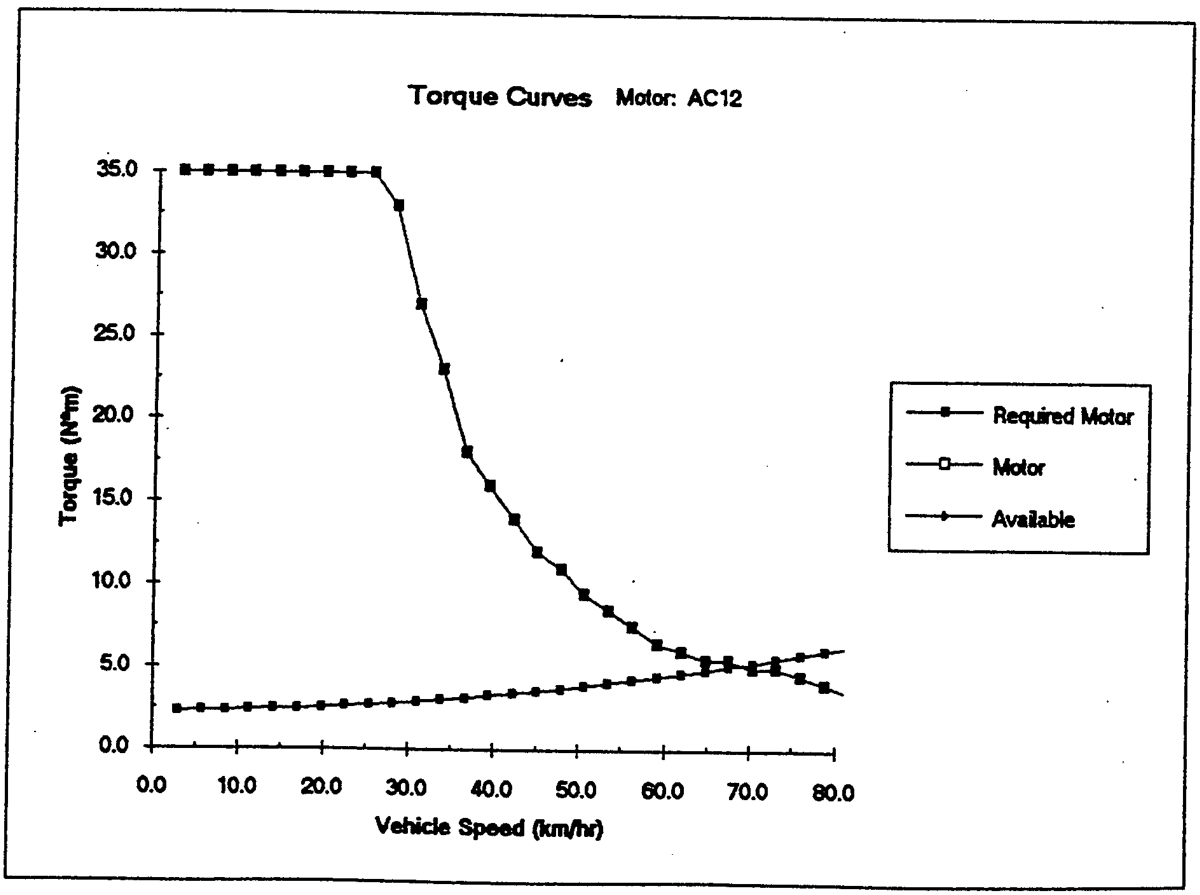
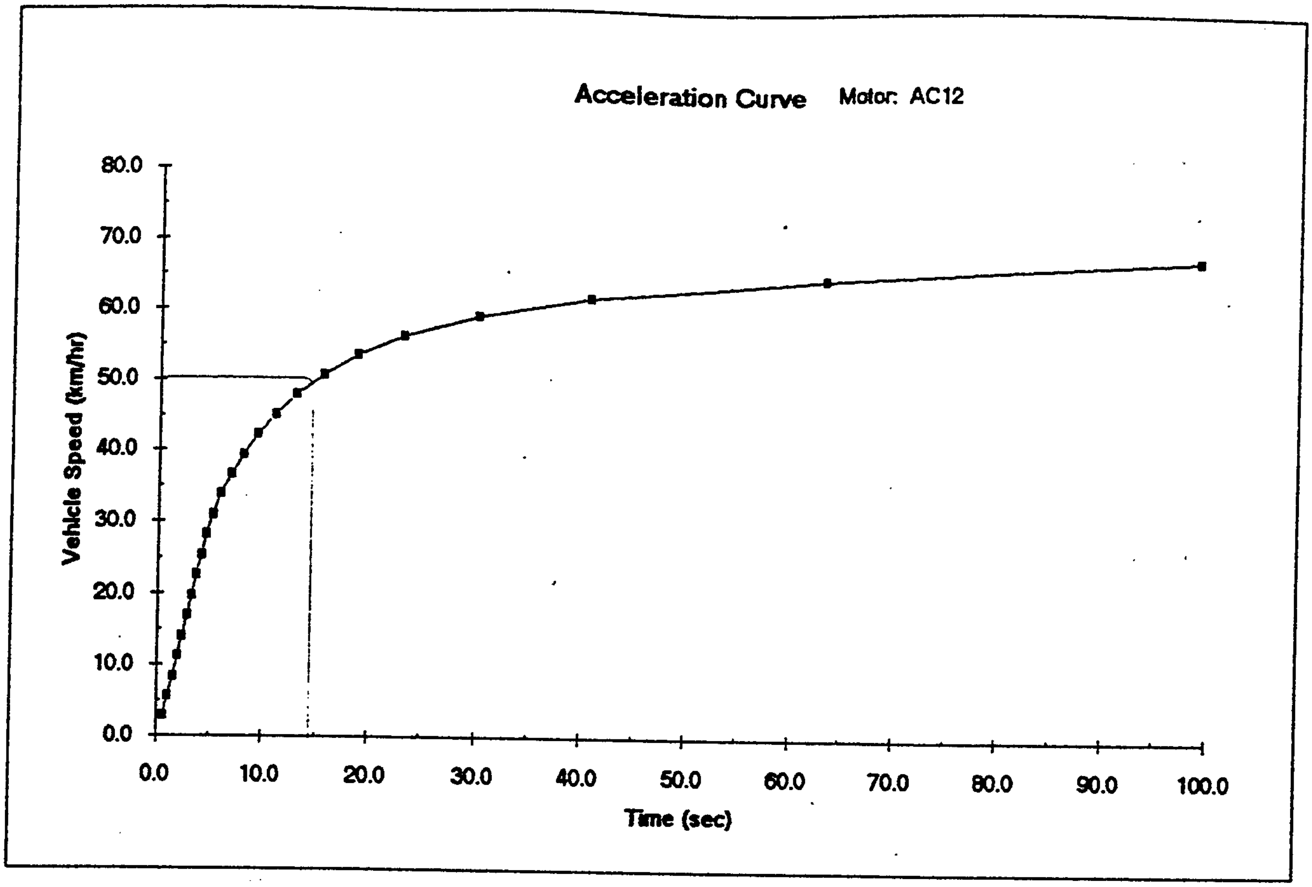
5500	5750	6000	6250	6500	6750	7000	7250	7500	7750
26.5	26	25.5	25	24.5	23.5	21.5	20	17	10
92%	92%	93%	93%	94%	95%	95%	95%	95%	95%
576.0	602.1	628.3	654.5	680.7	706.9	733.0	759.2	785.4	811.6
15262.9	15655.6	16022.1	16362.4	16676.6	16611.2	15760.3	15184.4	13351.8	8115.8
10	10	10	10	10	10	10	10	10	10
57.6	60.2	62.8	65.4	68.1	70.7	73.3	75.9	78.5	81.2
550.0	575.0	600.0	625.0	650.0	675.0	700.0	725.0	750.0	775.0
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
56.7	59.3	61.9	64.4	67.0	69.6	72.2	74.8	77.3	79.9
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0
67.1	73.3	79.9	86.7	93.7	101.1	108.7	116.6	124.8	133.2
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	400	400	400	400	400	400	400	400	400
180	180	180	180	180	180	180	180	180	180
580	580	580	580	580	580	580	580	580	580
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
3.2	3.3	3.5	3.6	3.7	3.9	4.0	4.2	4.3	4.5
149.9	156.3	163.0	169.9	177.1	184.6	192.4	200.4	208.8	217.4
2361.8	2574.2	2800.6	3041.5	3297.5	3569.2	3857.1	4162.0	4484.3	4824.7
41.0	42.8	44.6	46.5	48.4	50.5	52.6	54.8	57.1	59.4
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
2714.7	2958.9	3219.1	3496.0	3790.2	4102.5	4433.5	4783.9	5154.4	5545.6
4.7	4.9	5.1	5.3	5.6	5.8	6.0	6.3	6.6	6.8
72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
15840.0	15840.0	15840.0	15840.0	15840.0	15840.0	15840.0	15840.0	14640.1	8898.9
220.0	220.0	220.0	220.0	220.0	220.0	220.0	220.0	203.3	123.6
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
15206.4	15206.4	15206.4	15206.4	15206.4	15206.4	15206.4	15206.4	14054.5	8542.9
211.2	211.2	211.2	211.2	211.2	211.2	211.2	211.2	195.2	118.7
13989.9	13989.9	14142.0	14142.0	14294.0	14446.1	14446.1	14446.1	13351.8	8115.8
24.3	23.2	22.5	21.6	21.0	20.4	19.7	19.0	17.0	10.0
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
211.3	202.1	195.8	188.0	182.7	177.8	171.5	165.5	147.9	87.0
772.7	739.1	716.0	687.3	668.0	650.1	626.9	605.3	540.8	318.1
0.98	0.91	0.87	0.81	0.77	0.73	0.68	0.63	0.52	0.16
12.9	13.7	14.5	15.4	16.3	17.3	18.3	19.5	20.8	23.1

A3-20


Power Curves Motor: AC12
Power (Watts)
18000.0
17000.0
16000.0
15000.0
14000.0
13000.0
12000.0
11000.0
10000.0
9000.0
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Vehicle Speed (km/hr)
Required
Motor
Avail. Motor
Avail. Battery
Used Battery


Torque Curves Motor: AC12
Torque (N*m)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
Vehicle Speed (km/hr)
Required Motor
Motor
Available

A3.21


Acceleration Curve Motor: AC12
Vehicle Speed (km/hr)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Time (sec)

A3-22

Pacific EV Vehicle Performance Model   Motor: AC12

Motor Speed (rpm)	300	600	900	1200	1500	1800	2100	2400	2700
Max Motor Torque (N*m)	35	35	35	35	35	35	35	35	35
Eff. at Max Power (%)	65%	66%	68%	70%	72%	73%	74%	77%	80%
Motor Speed (rad/s)	31.4	62.8	94.2	125.7	157.1	188.5	219.9	251.3	282.7
Max Motor Power (W)	1099.6	2199.1	3298.7	4398.2	5497.8	6597.3	7696.9	8796.5	9896.0

Drive Ratio	11	11	11	11	11	11	11	11	11
Wheel Speed (rad/s)	2.9	5.7	8.6	11.4	14.3	17.1	20.0	22.8	25.7
Wheel Speed (rpm)	27.3	54.5	81.8	109.1	136.4	163.6	190.9	218.2	245.5
Tire Diameter (m)	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
Vehicle Speed (km/hr)	2.8	5.6	8.4	11.2	14.1	16.9	19.7	22.5	25.3
Drag Coeff. Cd	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Frontal Area (m^2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Air Density (kg/m^3)	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
Head Wind (km/hr)	0	0	0	0	0	0	0	0	0
F wind (N)	0.2	0.7	1.5	2.6	4.1	5.9	8.1	10.6	13.4
Percent Grade	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vehicle Mass (kg)	400	400	400	400	400	400	400	400	400
Passenger + Cargo Mass (kg)	180	180	180	180	180	180	180	180	180
Total Mass (kg)	580	580	580	580	580	580	580	580	580
Crr1 (Rolling Resistance)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
F grade (N)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F roll (N)	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
Crr2 (Wheel Windage)	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
F windage (N)	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.4
F total (N)	80.0	80.6	81.6	82.9	84.6	86.5	88.8	91.5	94.4
Wheel Power (W)	62.5	126.0	191.2	259.1	330.3	405.6	485.8	571.6	663.9
Wheel Torque (N*m)	21.9	22.1	22.3	22.7	23.1	23.7	24.3	25.0	25.8
Mechanical Eff.	87%	87%	87%	87%	87%	87%	87%	87%	87%
Required Motor Power (W)	71.8	144.8	219.8	297.8	379.6	466.2	558.3	657.0	763.1
Required Motor Torque (N*m)	2.3	2.3	2.3	2.4	2.4	2.5	2.5	2.6	2.7

Nom. Batt. Voltage (V)	72	72	72	72	72	72	72	72	72
Max Batt. Current (A)	220	220	220	220	220	220	220	220	220
Max Batt Power (W)	15840	15840	15840	15840	15840	15840	15840	15840	15840
Amp. Power (W)	1780.7	3507.4	5106.3	6613.9	8037.7	9513.1	10948.6	12025.2	13021.1
Amp. Current (A)	24.7	48.7	70.9	91.9	111.6	132.1	152.1	167.0	180.8
Amplifier Eff. (from Graph?)	95%	95%	95%	95%	95%	95%	95%	95%	95%
Electrical Power (W)	1691.6	3332.0	4851.0	6283.2	7635.8	9037.5	10401.2	11424.0	12370.0
Motor Current (A)	23.5	46.3	67.4	87.3	106.1	125.5	144.5	158.7	171.8
Max Avail. Motor Power (W)	1099.6	2199.1	3298.7	4398.2	5497.8	6597.3	7696.9	8796.5	9896.0
Max Avail. Motor Torque (N*m)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0

km (Rotational Inertia)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Max. Wheel Torque (N*m)	335.0	335.0	335.0	335.0	335.0	335.0	335.0	335.0	335.0
Max. Wheel Force (N)	1224.7	1224.7	1224.7	1224.7	1224.7	1224.7	1224.7	1224.7	1224.7
Accel. (m/s^2)	1.79	1.79	1.79	1.79	1.79	1.78	1.78	1.78	1.77
Accel Time (s)	0.7	1.1	1.5	2.0	2.4	2.8	3.3	3.7	4.2

A3-23

3000	3300	3600	3900	4200	4500	4800	5100	5400	5700	6000	6300
33	27	23	18	16	14	12	11	9.5	8.5	7.5	6.5
82%	82%	83%	86%	87%	88%	87%	86%	86%	86%	87%	86%
314.2	345.6	377.0	408.4	439.8	471.2	502.7	534.1	565.5	596.9	628.3	659.7
10367.2	9330.5	8670.8	7351.3	7037.2	6597.3	6031.9	5874.8	5372.1	5073.7	4712.4	4288.3

11	11	11	11	11	11	11	11	11	11	11	11
28.6	31.4	34.3	37.1	40.0	42.8	45.7	48.6	51.4	54.3	57.1	60.0
272.7	300.0	327.3	354.5	381.8	409.1	436.4	463.6	490.9	518.2	545.5	572.7
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
28.1	30.9	33.7	36.6	39.4	42.2	45.0	47.8	50.6	53.4	56.2	59.1

0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0	0	0
16.5	20.0	23.8	27.9	32.3	37.1	42.2	47.7	53.5	59.6	66.0	72.8
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	400	400	400	400	400	400	400	400	400	400	400
180	180	180	180	180	180	180	180	180	180	180	180
580	580	580	580	580	580	580	580	580	580	580	580
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
1.6	1.7	1.9	2.0	2.2	2.4	2.5	2.7	2.8	3.0	3.1	3.3
97.7	101.3	105.3	109.6	114.2	119.1	124.4	130.0	135.9	142.2	148.8	155.7
763.4	870.8	987.0	1112.8	1248.8	1395.9	1554.8	1726.4	1911.4	2110.5	2324.6	2554.3
26.7	27.7	28.8	30.0	31.2	32.6	34.0	35.6	37.2	38.9	40.7	42.6
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
877.4	1000.9	1134.5	1279.0	1435.4	1604.5	1787.2	1984.4	2197.0	2425.9	2671.9	2936.0
2.8	2.9	3.0	3.1	3.3	3.4	3.6	3.7	3.9	4.1	4.3	4.5

72	72	72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
13308.4	11977.6	10996.6	8997.9	8514.4	7891.6	7298.1	7190.7	6575.4	6210.1	5734.6	5248.8
184.8	166.4	152.7	125.0	118.3	109.6	101.4	99.9	91.3	86.3	79.6	72.9
95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
12643.0	11378.7	10446.7	8548.0	8088.7	7497.0	6933.2	6831.1	6246.6	5899.6	5447.8	4986.4
175.6	158.0	145.1	118.7	112.3	104.1	96.3	94.9	86.8	81.9	75.7	69.3
10367.2	9330.5	8670.8	7351.3	7037.2	6597.3	6031.9	5874.8	5372.1	5073.7	4712.4	4288.3
33.0	27.0	23.0	18.0	16.0	14.0	12.0	11.0	9.5	8.5	7.5	6.5

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
315.8	258.4	220.1	172.3	153.1	134.0	114.8	105.3	90.9	81.3	71.8	62.2
1154.7	944.8	804.8	629.8	559.9	489.9	419.9	384.9	332.4	297.4	262.4	227.4
1.66	1.32	1.10	0.82	0.70	0.58	0.46	0.40	0.31	0.24	0.18	0.11
4.6	5.2	5.9	6.9	8.0	9.4	11.0	13.0	15.5	18.7	23.1	30.1

A3-24

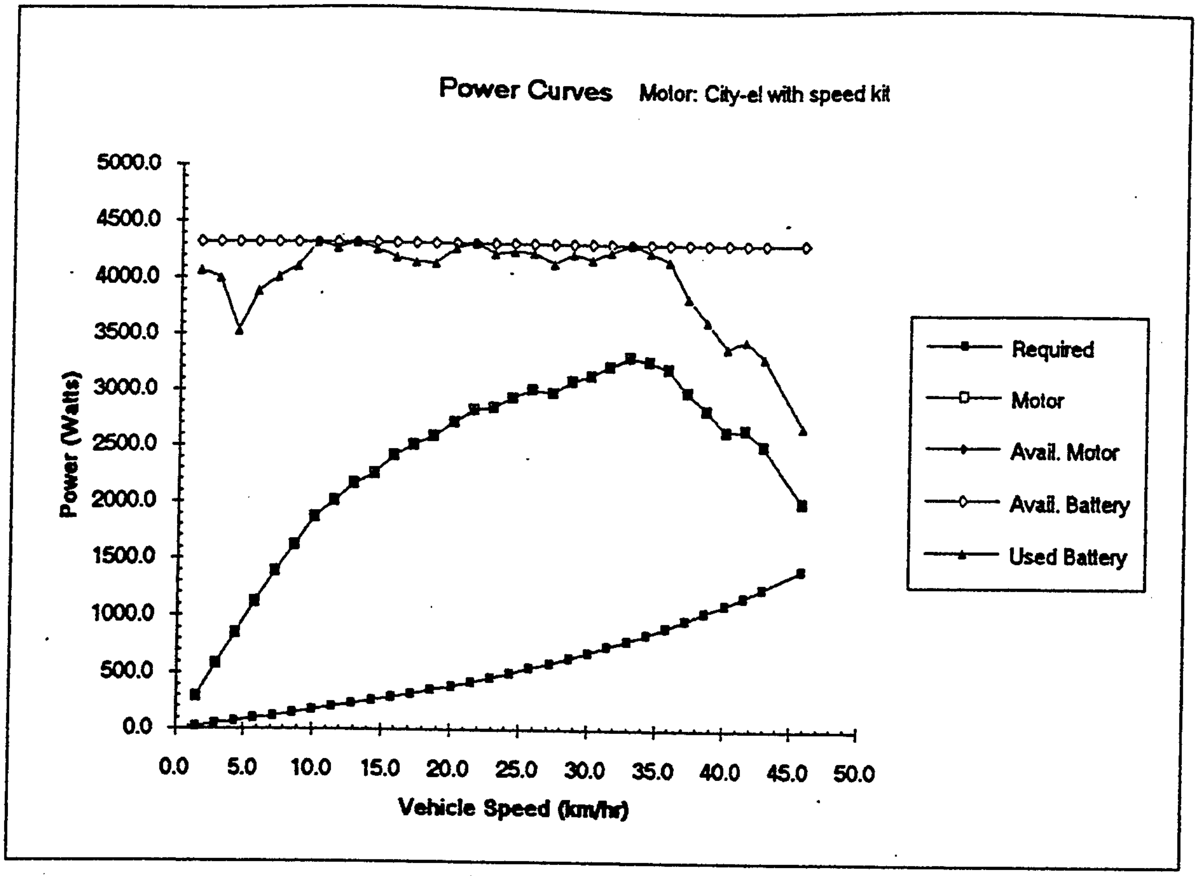
6600	6900	7200	7500	7800	8100	8400	8700	9000	9300
6	5.5	5.5	5	5	4.5	4	3.5	3.5	3
85%	84%	84%	84%	83%	81%	80%	79%	78%	76%
691.1	722.6	754.0	785.4	816.8	848.2	879.6	911.1	942.5	973.9
4146.9	3974.1	4146.9	3927.0	4084.1	3817.0	3518.6	3188.7	3298.7	2921.7

11	11	11	11	11	11	11	11	11	11
62.8	65.7	68.5	71.4	74.3	77.1	80.0	82.8	85.7	88.5
600.0	627.3	654.5	681.8	709.1	736.4	763.6	790.9	818.2	845.5
0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547	0.547
61.9	64.7	67.5	70.3	73.1	75.9	78.7	81.5	84.4	87.2
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0
79.9	87.3	95.0	103.1	111.5	120.3	129.4	138.8	148.5	158.6
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
400	400	400	400	400	400	400	400	400	400
180	180	180	180	180	180	180	180	180	180
580	580	580	580	580	580	580	580	580	580
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7	79.7
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
3.5	3.6	3.8	3.9	4.1	4.2	4.4	4.5	4.7	4.9
163.0	170.6	178.5	186.7	195.3	204.2	213.4	223.0	232.9	243.1
2800.6	3064.1	3345.7	3646.0	3966.0	4306.3	4667.7	5051.0	5457.0	5886.4
44.6	46.6	48.8	51.1	53.4	55.8	58.4	61.0	63.7	66.5
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
3219.1	3522.0	3845.6	4190.9	4558.6	4949.7	5365.2	5805.8	6272.4	6766.0
4.7	4.9	5.1	5.3	5.6	5.8	6.1	6.4	6.7	6.9

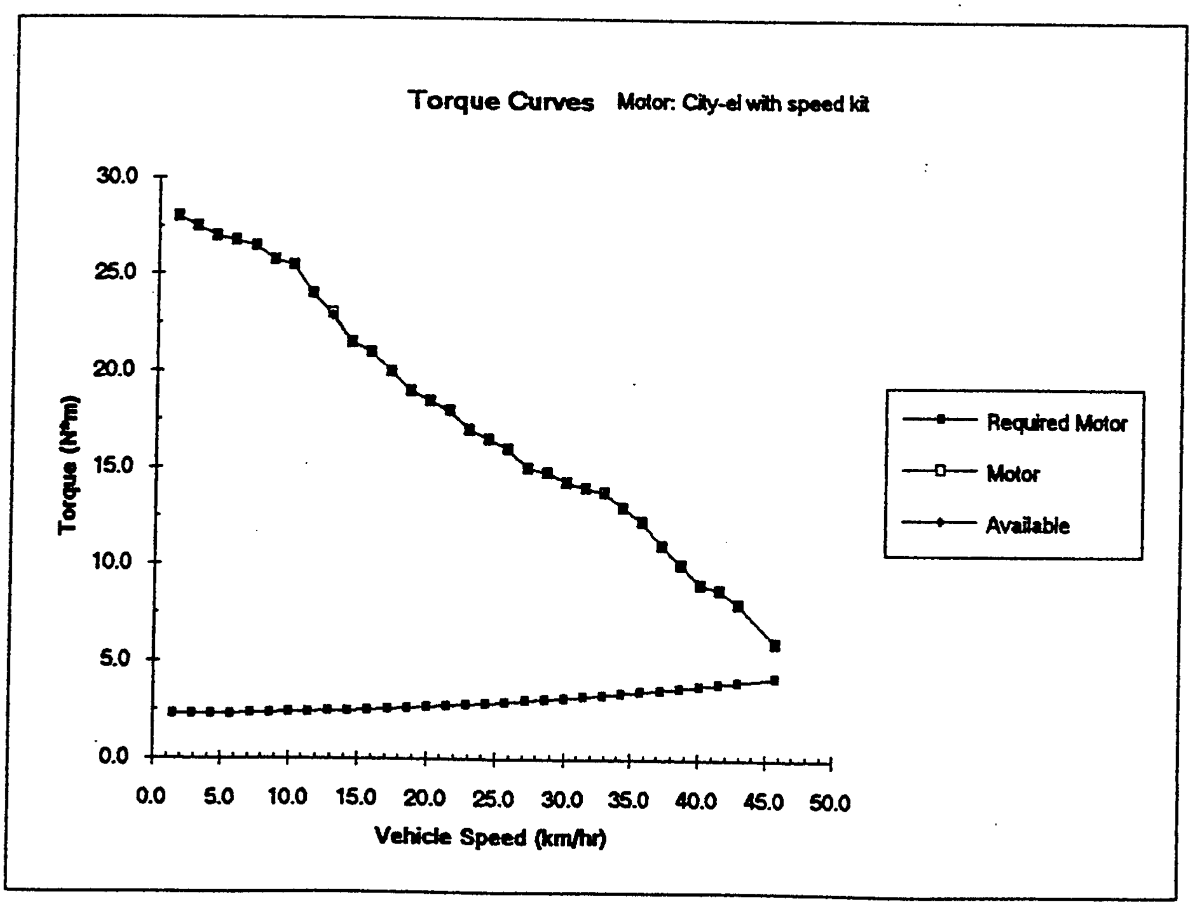
72	72	72	72	72	72	72	72	72	72
220	220	220	220	220	220	220	220	220	220
15840	15840	15840	15840	15840	15840	15840	15840	15840	15840
5135.5	4980.1	5196.6	4921.0	5179.5	4960.4	4629.7	4248.8	4451.6	4046.6
71.3	69.2	72.2	68.3	71.9	68.9	64.3	59.0	61.8	56.2
95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
4878.7	4731.1	4936.8	4675.0	4920.6	4712.4	4398.2	4036.3	4229.1	3844.3
67.8	65.7	68.6	64.9	68.3	65.4	61.1	56.1	58.7	53.4
4146.9	3974.1	4146.9	3927.0	4084.1	3817.0	3518.6	3188.7	3298.7	2921.7
6.0	5.5	5.5	5.0	5.0	4.5	4.0	3.5	3.5	3.0

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
57.4	52.6	52.6	47.9	47.9	43.1	38.3	33.5	33.5	28.7
209.9	192.4	192.4	175.0	175.0	157.5	140.0	122.5	122.5	105.0
0.07	0.03	0.02	-0.02	-0.03	-0.07	-0.12	-0.16	-0.17	-0.22
40.7	63.4	99.1	56.7	32.2	21.5	14.7	9.8	5.3	3.5

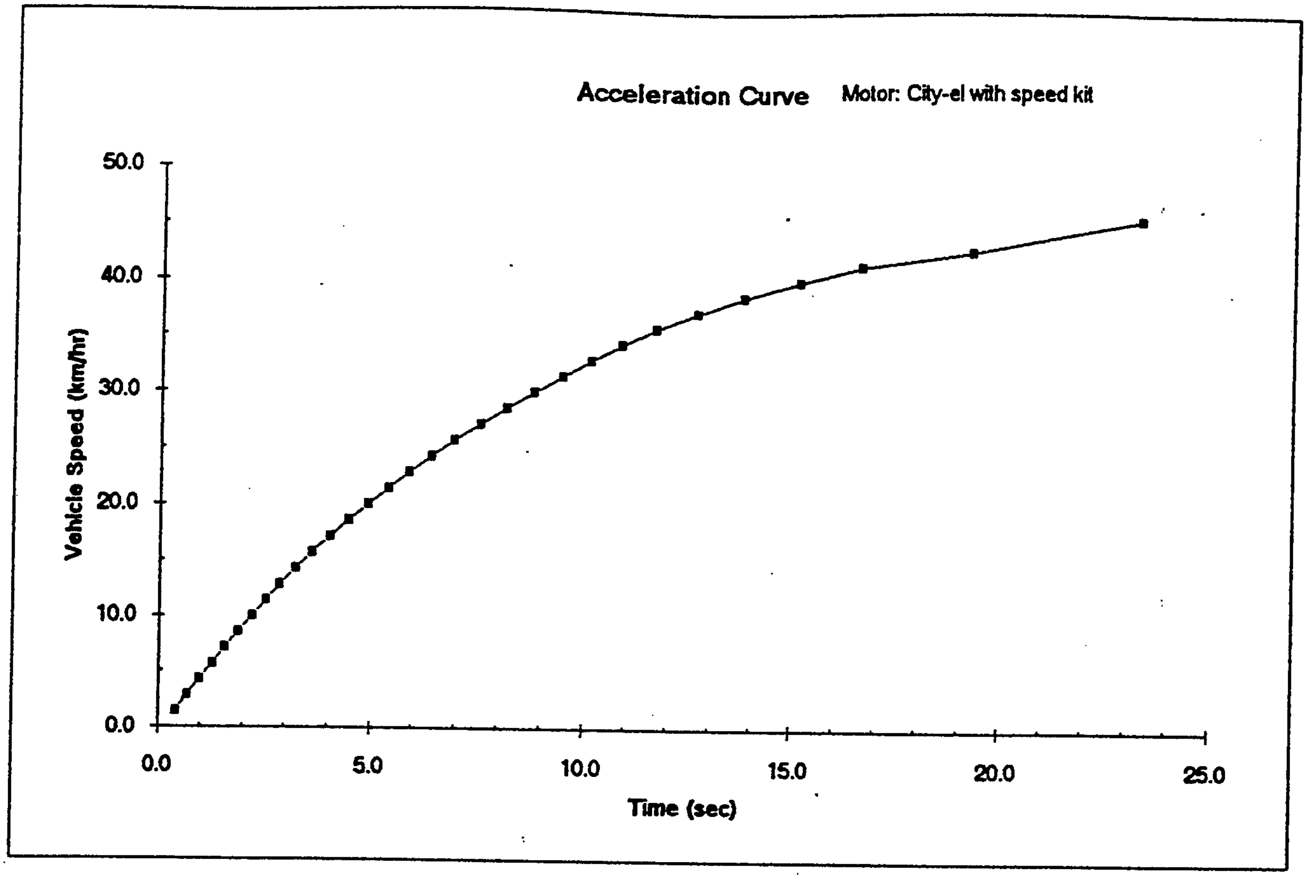
A3-25



Note:
10% grade
17 k/hr



A3-26


Acceleration Curve
Motor: City-el with speed kit
Vehicle Speed (km/hr)
50.0
40.0
30.0
20.0
10.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
Time (sec)

A3-27

Pacific EV Vehicle Performance Model

Motor: City-el with speed kit

Motor Speed (rpm)	100	200	300	400	500	600	700	800	900
Max Motor Torque (N*m)	28	27.5	27	26.75	26.5	25.75	25.5	24	23
Eff. at Max Power (%)	8%	15%	25%	30%	36%	41%	45%	49%	52%
Motor Speed (rad/s)	10.5	20.9	31.4	41.9	52.4	62.8	73.3	83.8	94.2
Max Motor Power (W)	293.2	576.0	848.2	1120.5	1387.5	1617.9	1869.2	2010.6	2167.7
Drive Ratio	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83
Wheel Speed (rad/s)	1.5	3.1	4.6	6.1	7.7	9.2	10.7	12.3	13.8
Wheel Speed (rpm)	14.6	29.3	43.9	58.6	73.2	87.8	102.5	117.1	131.8
Tire Diameter (m)	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518
Vehicle Speed (km/hr)	1.4	2.9	4.3	5.7	7.1	8.6	10.0	11.4	12.9
Drag Coeff. Cd	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Frontal Area (m^2)	1	1	1	1	1	1	1	1	1
Air Density (kg/m^3)	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
Head Wind (km/hr)	0	0	0	0	0	0	0	0	0
F wind (N)	0.0	0.2	0.4	0.7	1.1	1.5	2.1	2.7	3.5
Percent Grade	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vehicle Mass (kg)	290	290	290	290	290	290	290	290	290
Passenger + Cargo Mass (kg)	85	85	85	85	85	85	85	85	85
Total Mass (kg)	375	375	375	375	375	375	375	375	375
Crr1 (Rolling Resistance)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
F grade (N)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F roll (N)	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5
Crr2 (Wheel Windage)	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
F windage (N)	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5
F total (N)	51.6	51.8	52.1	52.4	52.9	53.4	54.0	54.7	55.5
Wheel Power (W)	20.5	41.1	62.0	83.3	105.0	127.2	150.1	173.8	198.3
Wheel Torque (N*m)	13.4	13.4	13.5	13.6	13.7	13.8	14.0	14.2	14.4
Mechanical Eff.	87%	87%	87%	87%	87%	87%	87%	87%	87%
Required Motor Power (W)	23.6	47.3	71.3	95.7	120.7	146.2	172.6	199.8	228.0
Required Motor Torque (N*m)	2.2	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.4
Nom. Batt. Voltage (V)	36	36	36	36	36	36	36	36	36
Max Batt. Current (A)	120	120	120	120	120	120	120	120	120
Max Batt Power (W)	4320	4320	4320	4320	4320	4320	4320	4320	4320
Amp. Power (W)	4072.4	3999.7	3534.3	3890.6	4014.9	4110.6	4320.0	4274.3	4320.0
Amp. Current (A)	113.1	111.1	98.2	108.1	111.5	114.2	120.0	118.7	120.0
Amplifier Eff. (from Graph?)	96%	96%	96%	96%	96%	96%	96%	96%	96%
Electrical Power (W)	3909.5	3839.7	3392.9	3735.0	3854.3	3946.1	4147.2	4103.3	4147.2
Motor Current (A)	108.6	106.7	94.2	103.8	107.1	109.6	115.2	114.0	115.2
Max Avail. Motor Power (W)	293.2	576.0	848.2	1120.5	1387.5	1617.9	1866.2	2010.6	2156.5
Max Avail. Motor Torque (N*m)	28.0	27.5	27.0	26.8	26.5	25.8	25.5	24.0	22.9
km (Rotational Inertia)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Max. Wheel Torque (N*m)	166.4	163.4	160.4	159.0	157.5	153.0	151.3	142.6	136.0
Max. Wheel Force (N)	642.4	630.9	619.4	613.7	608.0	590.8	584.1	550.6	525.0
Accel. (m/s^2)	1.43	1.40	1.38	1.36	1.35	1.30	1.29	1.20	1.14
Accel Time (s)	0.4	0.7	1.0	1.3	1.6	1.9	2.2	2.5	2.9

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1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100
21.5	21	20	19	18.5	18	17	16.5	16	15	14.75	14.25
55%	60%	63%	65%	66%	68%	70%	72%	74%	75%	76%	78%
104.7	115.2	125.7	136.1	146.6	157.1	167.6	178.0	188.5	199.0	209.4	219.9
2251.5	2419.0	2513.3	2586.6	2712.2	2827.4	2848.4	2937.4	3015.9	2984.5	3089.2	3133.7

6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83
15.3	16.9	18.4	19.9	21.5	23.0	24.5	26.1	27.6	29.1	30.7	32.2
146.4	161.1	175.7	190.3	205.0	219.6	234.3	248.9	263.5	278.2	292.8	307.5
0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518
14.3	15.7	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.6	30.0

0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1	1	1	1	1	1	1	1	1	1	1	1
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0	0	0
4.3	5.2	6.1	7.2	8.4	9.6	10.9	12.3	13.8	15.4	17.1	18.8
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
290	290	290	290	290	290	290	290	290	290	290	290
85	85	85	85	85	85	85	85	85	85	85	85
375	375	375	375	375	375	375	375	375	375	375	375
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.1	1.2	1.3
56.4	57.3	58.4	59.5	60.7	62.0	63.4	64.8	66.4	68.0	69.8	71.6
223.8	250.4	278.1	307.1	337.5	369.3	402.7	437.8	474.6	513.3	554.0	596.8
14.6	14.8	15.1	15.4	15.7	16.1	16.4	16.8	17.2	17.6	18.1	18.5
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
257.3	287.8	319.7	353.0	387.9	424.5	462.9	503.2	545.5	590.0	636.8	686.0
2.5	2.5	2.5	2.6	2.6	2.7	2.8	2.8	2.9	3.0	3.0	3.1

36	36	36	36	36	36	36	36	36	36	36	36
120	120	120	120	120	120	120	120	120	120	120	120
4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320	4320
4264.2	4199.7	4155.5	4145.2	4280.7	4320.0	4238.7	4249.7	4245.4	4145.2	4234.1	4185.0
118.4	116.7	115.4	115.1	118.9	120.0	117.7	118.0	117.9	115.1	117.6	116.3
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
4093.6	4031.7	3989.3	3979.3	4109.5	4147.2	4069.1	4079.7	4075.6	3979.3	4064.8	4017.6
113.7	112.0	110.8	110.5	114.2	115.2	113.0	113.3	113.2	110.5	112.9	111.6
2251.5	2419.0	2513.3	2586.6	2712.2	2820.1	2848.4	2937.4	3015.9	2984.5	3089.2	3133.7
21.5	21.0	20.0	19.0	18.5	18.0	17.0	16.5	16.0	15.0	14.8	14.3

4 hp. at 1750 RPM.

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
127.8	124.8	118.8	112.9	109.9	106.7	101.0	98.0	95.1	89.1	87.6	84.7
493.3	481.8	458.8	435.9	424.4	411.9	390.0	378.6	367.1	344.1	338.4	326.9
1.06	1.03	0.97	0.91	0.88	0.85	0.79	0.76	0.73	0.67	0.65	0.62
3.2	3.6	4.0	4.5	4.9	5.4	5.9	6.4	7.0	7.6	8.2	8.8

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2200	2300	2400	2500	2600	2700	2800	2900	3000	3200
14	13.75	13	12.25	11	10	9	8.75	8	6
79%	80%	80%	80%	81%	81%	81%	80%	79%	78%
230.4	240.9	251.3	261.8	272.3	282.7	293.2	303.7	314.2	335.1
3225.4	3311.8	3267.3	3207.0	2995.0	2827.4	2638.9	2657.3	2513.3	2010.6

6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83	6.83
33.7	35.3	36.8	38.3	39.9	41.4	42.9	44.5	46.0	49.1
322.1	336.7	351.4	366.0	380.7	395.3	410.0	424.6	439.2	468.5
0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518	0.518
31.5	32.9	34.3	35.7	37.2	38.6	40.0	41.5	42.9	45.7

0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1	1	1	1	1	1	1	1	1	1
1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202	1.202
0	0	0	0	0	0	0	0	0	0
20.6	22.6	24.6	26.7	28.8	31.1	33.4	35.9	38.4	43.7
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
290	290	290	290	290	290	290	290	290	290
85	85	85	85	85	85	85	85	85	85
375	375	375	375	375	375	375	375	375	375
0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5
0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502	0.0502
1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9
73.5	75.4	77.5	79.7	81.9	84.2	86.6	89.1	91.7	97.1
641.8	689.0	738.6	790.8	845.5	902.9	963.0	1026.1	1092.2	1233.7
19.0	19.5	20.1	20.6	21.2	21.8	22.4	23.1	23.7	25.1
87%	87%	87%	87%	87%	87%	87%	87%	87%	87%
737.7	792.0	849.0	908.9	971.8	1037.8	1107.0	1179.5	1255.4	1418.1
3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.2

36	36	36	36	36	36	36	36	36	36
120	120	120	120	120	120	120	120	120	120
4320	4320	4320	4320	4320	4320	4320	4320	4320	4320
4252.9	4320.0	4254.2	4175.8	3851.6	3636.1	3393.7	3460.0	3313.9	2685.1
118.1	120.0	118.2	116.0	107.0	101.0	94.3	96.1	92.1	74.6
96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
4082.7	4147.2	4084.1	4008.8	3697.5	3490.7	3257.9	3321.6	3181.4	2577.7
113.4	115.2	113.4	111.4	102.7	97.0	90.5	92.3	88.4	71.6
3225.4	3297.0	3267.3	3207.0	2995.0	2827.4	2638.9	2657.3	2513.3	2010.6
14.0	13.7	13.0	12.3	11.0	10.0	9.0	8.8	8.0	6.0

1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
83.2	81.3	77.2	72.8	65.4	59.4	53.5	52.0	47.5	35.7
321.2	314.1	298.3	281.0	252.4	229.4	206.5	200.7	183.5	137.7
0.60	0.58	0.54	0.49	0.41	0.35	0.29	0.27	0.22	0.10
9.5	10.2	10.9	11.7	12.7	13.8	15.2	16.6	19.3	23.3

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Appendix

	Cost (1)	Weight (kg)
Motor, Advanced DC k-91	$630.00	26.00
Controller, Curtis 1209 R	$1,530.00	6.50
Main contactor, SW180B-xx 12CO	$100.00	0.64
Regen Contactor, SW200A-16 12CO	$115.00	1.35
Drive Contactor, SW200A-16 12CO	$115.00	1.35
F-R Contactor, SW192B-2 12CO	$174.20	1.66
Potentiometer, Regen, Curtis PB-8, 0-5k, with switch, 3 wi	$50.00	0.50
Potentiometer, Drive, Curtis PB-6, 0-5k, with switch, 2 wire	$50.00	0.50
forward reverse switch	$20.00	0.10
regen relay	$15.00	0.10
Total:	$2,799.20	38.70
Differential: Club Car	$613.26	9.50
Sprocket	$60.00	2.00
Sprocket	$35.00	1.00
Gates Belt	$60.00	1.00
	$768.26	13.50

BRLS-11	Cost	Weight (kg)	
BRLS-11 Motor	$2,980.00	14.55	
BRLS-250 Controller	$3,850.00	6.80	
Solectria ABC 1	$40.00	0.15	
Solectria ABC 1	$40.00	0.15	
Forward Reverse SW.	$200.00	0.40	
Wye-Delta Switch	$316.00	0.52	
	$7,110.00	22.05	
Reducing Differential.	$1,350.00	13.60	

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AC-12	Cost	Weight
AC-12 Motor	$1,480.00	23.00
AC-220 Controller	$5,890.00	8.60
Solectria ABC 1	$40.00	0.15
Solectria ABC 1	$40.00	0.15
Forward Reverse SW.	$200.00	0.40
Wye-Delta Switch	$316.00	0.52
Total:	$7,966.00	32.82

BPM-8	Cost	Weight (kg)
BPM-8 Motor	$1,070	24.54
DC-200 Controller	$990	1.8
Main contactor, SW180B-xx 12CO	$100	0.64
Solectria ABC 1	$40	0.15
Solectria ABC 1	$40	0.15
Forward Reverse SW.	$200	0.40
Total:	$2,440	27.68

PACIFIC ELECTRIC VEHICLES

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30 June, 1995

Sacramento Municipal Utility District
Electric Transportation Dept.
PO Box 15830 MS 30A
Sacramento, CA. 95852-1830

Attention: Mr. Steve Rutter

Subject: Preliminary Battery Life Report

Dear Steve,

Pacific EV is pleased to submit the enclosed "City-el Battery Life, Preliminary Report". A copy of this report is being sent to our lease customers for information. It appears the longest battery life is being achieved by daily charging. We would appreciate SMUD's suggestions for estimating the number of cycles on the batteries using data acquired as a part of the project.

Should there be questions regarding the enclosed report, please call.

Best Regards,

Bill

W.R. Warf
Pacific EV

c: Phil Mook
Lease Customers

City-el Battery Life, Preliminary Report.

12 June, 1995

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins and William R. Warf
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

REPORT: City-el Battery Life, Preliminary Report.
Prepared by: Lance Atkins and William Warf, Pacific Electric Vehicles, 6-12-95

Background: As of February, 1995 the Neighborhood Electric Vehicle project had accumulated 33,968 City-el miles since the beginning of vehicle deployment in December, 1993. An average of 35 vehicles were deployed during this period. A few of the City-els deployed during this time had batteries fail.

Scope: This report reviews the status of batteries in deployed project vehicles through February, 1995, with emphasis on five vehicles which have had battery failures. Four other vehicles without battery failures are included in the analysis for comparison and broaden the sample to nine vehicles. This is a preliminary report because it appears that 6 vehicles need a battery change now, and approximately another 6 will require new batteries before the end of the project. A more complete report can be prepared near the end of the project.

Of the five City-els with failed batteries, three had Trojan 30XHs batteries installed at the beginning of the project. The other two vehicles had GNB EVB-1180 batteries installed during June, 1994. Two vehicles included in this report had Trojan batteries installed at the beginning of the project and were still operating on the original batteries. One of these had provided more than 3598 miles, and the Trojan 30XHs battery pack continued to give satisfactory performance except for a low voltage indication on longer trips. The two other vehicles included in this report had GNB EVB-1180 batteries installed in July.

This report is also a first attempt at utilizing DAS (data acquisition system) data to estimate the number of cycles the batteries have seen. Three of the vehicles considered by this report had batteries fail before the installation of the DAS, and are shown in the table City-el Preliminary Battery Life Report Data with 0 DAS days. Some ideas for additional analysis, and for the Final Battery Life report are noted.

The complete package of data used to generate this report has not been included but is available upon request. See the last page in this report for a complete list of available documents.

Conclusions: One Trojan 30XHs equipped vehicle had been driven 3598 miles, and had not yet suffered battery failure. This vehicle was driven an average of 8.1 miles per day, and was charged once daily. This suggests that the number of discharge-charge cycles was about 444. If the battery pack had stopped working February 17th, the batteries would have cost about 8 cents per mile. See the City-el: Energy and Battery Cost graph included in the appendix for a complete view of battery cost. Trojan estimates the cycle life of these 30XHs batteries as 325 cycles based on 80% DOD (depth of discharge).

Four project vehicles were equipped with GNB EVB-1180 batteries. Two of these packs failed. One failed after an estimated 305 cycles and 2354 miles. This operator drove an average of 11.75 miles per cycle, and did a significant amount of "opportunity charging". His daily travel needs required a charge 1.34 times per day. The second GNB pack to fail

had an estimated 188 cycles and 1238 miles. The two remaining GNB packs are still performing, and have fewer estimated discharge-charge cycles as shown in the attached table. One of these packs had one low-voltage-under-load battery replaced soon after being placed in service.

The City-el appears to achieve the highest battery life if it is charged daily. Mileage varies from 200 to 2354 for the five vehicles which have had battery packs changed. The estimated cycle life ranges from 85 to 305 cycles. The vehicle with the fewest miles also has the fewest number of discharge cycles, and was charged only as frequently as once every 4 days. See the Effect of Days per Cycle on City-el Battery Life graph included in the appendix.

At present, there is no information on the number of cycles that could be expected from the batteries based on their use pattern. Since the cycle life changes significantly based on the DOD, the vehicle use pattern needs to be considered. A program needs to be written that will process the DAS data and provide an estimate of the number of cycles that can be expected from the batteries. This estimate needs to include the self discharge of the City-el as well as the discharge from the trips between charges. It will also be important to consider the timing of the charges and discharges and the number of times the batteries had the plates exposed.

This is a preliminary report only, and a more detailed analysis will be done following completion of programs to analyze the DAS data.

Notes on the Data Used.

The raw data used for this report can be found in Pacific Electric Vehicles monthly data submittals to SMUD or, in the case of vehicle 4030, DAS data in Jose Baer's collection of DAS files from February, 1994 to April, 1994. Information on how this data was taken can be found in documents relating to the Data Collection Plan and in the DAS User's Manual and other DAS documents. A few notes about this data are included below, however, because they are particularly significant to this report.

It should be remembered that the data from the monthly service check was not necessarily taken with the batteries in the same state of charge. For instance, the batteries could have been fully charged, fully discharged, or somewhere in between including being charged at the time of service. Specific gravity readings are usually an eyeball average of several cells on each battery. In some cases, a detailed check of each cell has been done, and this has been noted where applicable. The batteries and their cells have been numbered using the following method. Batteries are numbered 1 to 3 from left to right as viewed from the rear of the City-el. Cells are numbered 1 to 6 for each battery starting with the cell nearest the positive terminal. Water use values can be considered accurate to the tenth of a liter. Generally, once the water use value reaches 2.9 liters the battery plates begin to be exposed. Finally, the AC-Wh readings recorded have not been adjusted for the 10% excess error of the Hydria meter. Totals used in this report though have been adjusted for this error.

Also realize that the City-el capacity gage allows 1200 to 1800 DC W-h to be withdrawn from the pack depending on the discharge rate (current) and battery temperature. Trojan 30XHs batteries are rated at 80 A-h (2832 W-h) at the 2 hour rate, and GNB EVB-1180 batteries are rated at 90 A-h (3186 W-h) at the 2 hour rate. Thus the capacity gage prevents discharging a City-el to more than 56% DOD for the Trojans, or 50% DOD for the GNBs.

The number of battery cycles has been estimated in two different ways using the monthly service data. First, the total miles traveled has been divided by the average miles per day or a multiple there of to get one battery cycle estimate. This estimate is based on the question "How far on average is the vehicle driven before it is plugged in?" In some cases, a multiple of the average miles per day has been used. This multiple is an estimate based on conversations with the user. The second way battery cycles were estimated was to divide the total AC-Wh used, by an average AC-Wh per charge. The value used for the average AC-Wh per charge is an estimate based on observations while using and testing the City-el over the last year. No doubt the DAS data could be used to generate a better average but that would require some programming time to create a program capable of processing enough files to generate a reasonable average.

DAS data, when available, has proven to be very helpful in evaluating the use pattern and number of cycles on a City-el's batteries. A few cautions are in order though. The DC-Whs recorded during a trip may not be very accurate. Recent preliminary tests show that the DAS can be off by about 25%. Charging data is periodically fraught with problems leaving data that is unclear. In addition, there may be other recording errors which have not yet been identified. Finally, the total number of battery cycles obtained from the DAS data is an extrapolation of the existing data. The total number of charges recorded by the DAS was divided by the number of days over which those charges took place. This average number of charges per day as documented by the DAS was multiplied by the total number of days in service to obtain an estimate of the total number of cycles.

The final set of data used in this report was Arthur Cartwright's manual records on City-el 4147. This data contains virtually all available information from the dashboard and the Hydria meter for the start and end of every charge on the vehicle. This data was carefully reviewed to determine the use pattern of the vehicle and the number of cycles on the batteries. No abnormalities in the data are known at this time.

Trojan Battery City-els

The Trojan batteries used in the City-els have been commonly referred to as Trojan 30XH batteries, and this is how they have been recorded on the monthly service checks. It appears however that the batteries are actually Trojan 30XHs batteries. The battery cases are not marked and the only discernible difference between the two is the weight. 30XH batteries weigh 58 lbs while 30XHs batteries weigh 66 lbs. A cursory check of some City-el batteries showed that they weighed 67 lbs or about the right weight to be 30XHs batteries.

The Trojan 30XHs batteries have 80 Ah (about 2832 Wh) capacity at the 2 hour rate and a life of 325 cycles based on the BCI cycle. According to Kitty Rodden of Trojan Battery Company the BCI cycle uses a 75 amp draw to 80% DOD based on a 1.75 VPC endpoint. She also points out that the depth of discharge affects the cycle life in a nonlinear fashion. As a rule of thumb there is a 50% increase in the number of cycles as DOD is drecreased from 80% DOD to 50% DOD and another 50% increase in the number of cycles as DOD is decreased from 50% DOD to 30% DOD.

All Trojan batteries were charged using the standard City-el charger. See charger reports for information on the charging profile of the standard City-el charger.

City-el 4032 has been in constant use by a private customer. The batteries were removed when the customer consistently got the low voltage light after using only 3 to 6 dots after a full charge. At this point use was impaired because of inadequate range. Estimated number of cycles before failure was 203. The average AC-Wh/mile was 365.5, and the plates were exposed on one occasion.

City-el 4126 spent some time at DEI before being used by a private customer. The batteries were removed before the vehicle was sent to Lawrence Livermoore National Laboratories because battery performance was suspect. Before removal, the batteries had about 140 cycles, but the plates were exposed 3 times. Average AC-Wh/mile was 354.4.

City-el 4133 has been used by McClellan AFB. The batteries were removed because they were starting to fail and to make room for the Inductran battery test. An estimated 85 cycles were on the batteries before they were removed. Average AC-Wh/mile was 1403.

City-el 4030 has been in constant use by a private customer. The batteries are starting to show signs of failure, but they are still providing adequate range and performance. As of February 16th these batteries had about 444 cycles. The plates may have been slightly exposed on 1 occasion, and the average AC-Wh/mile was 340.3. Average trip discharge was 921 Wh and about half of all charging was to the 100% level.

City-el 4129 has been in constant use by a private customer. The batteries have shown signs of failure, but are still providing the customer with adequate range and performance. These batteries, as of February 15, had about 190 cycles with an average discharge of 992 Wh. Just under half of all charging was to the 82% level. Average AC-Wh/mile was 324.6.

GNB Battery City-els

The GNB batteries used in the City-els were GNB 12-EVB-1180 batteries. Preliminary manufacture's specifications for this battery are as follows. Capacity is stated as 90 Ah at the 2 hour rate (about 3186 Wh) with an end point voltage of 1.70 VPC. Estimated cycle life is 750 cycles to 80% DOD.

All GNB batteries were charged using the GNB tuned City-el charger. See charger reports for information on the charging profile of this City-el charger.

Report: City-el Battery Life, Preliminary Report.

Five sets of batteries were received, but one set of batteries came with a battery that was bad leaving 4 good sets of batteries. one battery from the bad set was used to replace a battery failure in City-el 4142. The other battery is still available.

City-el 4144 was used exclusively by a private customer. The batteries were removed when they no longer provided sufficient range. The low voltage light came on after about 6 lights were used. Estimated number of charge cycles was 188 with an average discharge of 685 Wh. Almost all charging was done to the 100% level. Some solar charging experimentation was done on these batteries. Average AC-Wh/mile was 240.2.

City-el 4147 was used exclusively by a private customer. The batteries were removed when they no longer provided sufficient range. The low voltage light was coming on after 4 or 5 dots had been used. There were 305 cycles on the batteries before they were removed. Average discharge was estimated to be 734 Wh with almost all charges going to the 100% level. Average AC-Wh/mile was 201.1.

City-el 4142 has been used by McClellan AFB. Battery number 2 of this set was replaced in December, 1994 after it failed. Since then the batteries have been providing adequate range and performance for McClellan. As of February 13, these batteries had an estimated 70 cycles with an average discharge of 320 Wh. Almost all charges were to the 100% level. AC energy use was an average 639.8 AC-Wh/mile.

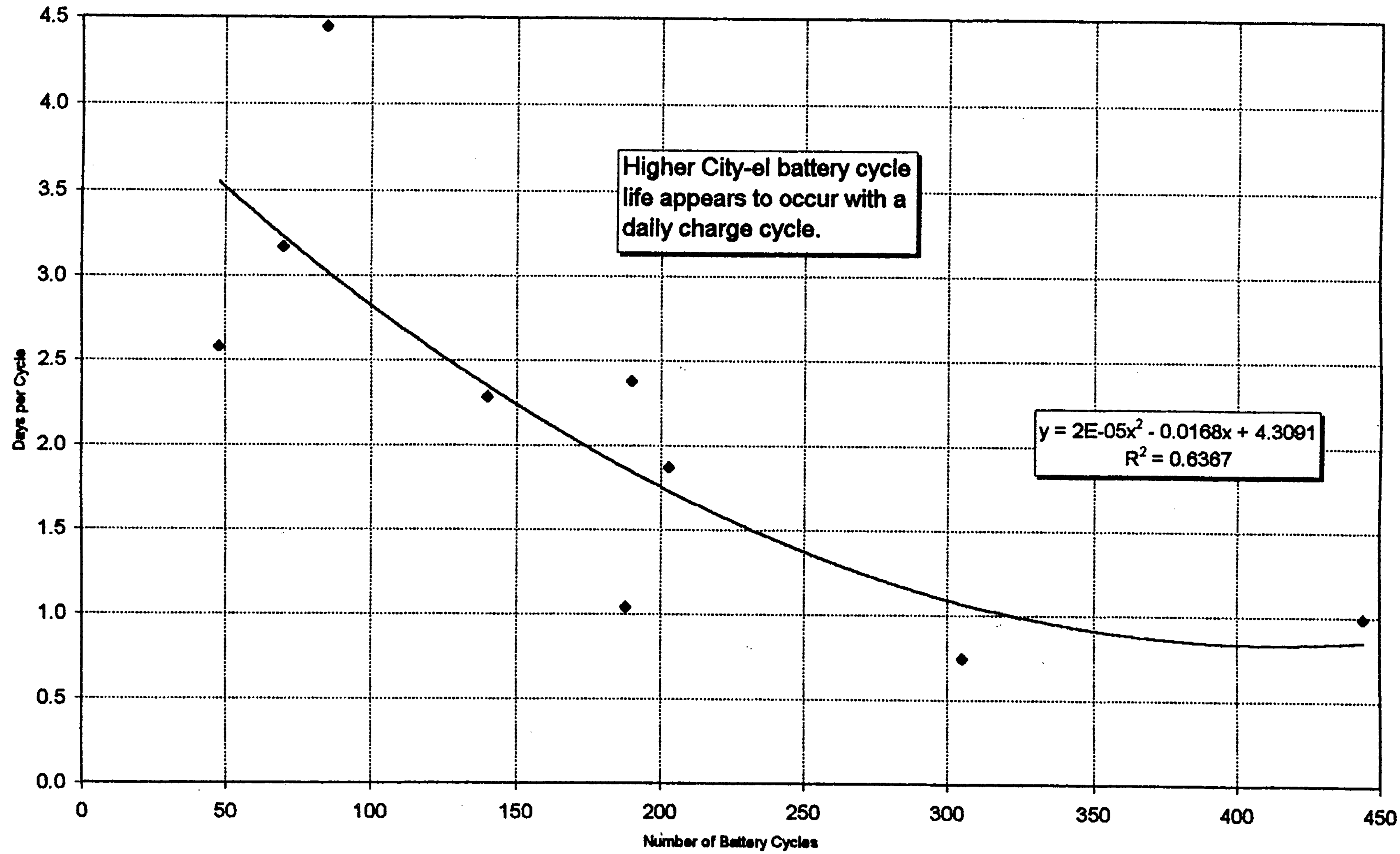
City-el 4143 has been in use by a private customer. The batteries have shown signs of failure, but they are still providing adequate range and performance. This set of batteries was used briefly in City-el 4141 before being installed in City-el 4143. The set has about 48 cycles with an average discharge of 628 Wh. Virtually all charging was to the 100% level. Energy use averaged 614.2 AC-Wh/mile.

APPENDIX

City-el Preliminary Batttery Life Report Data

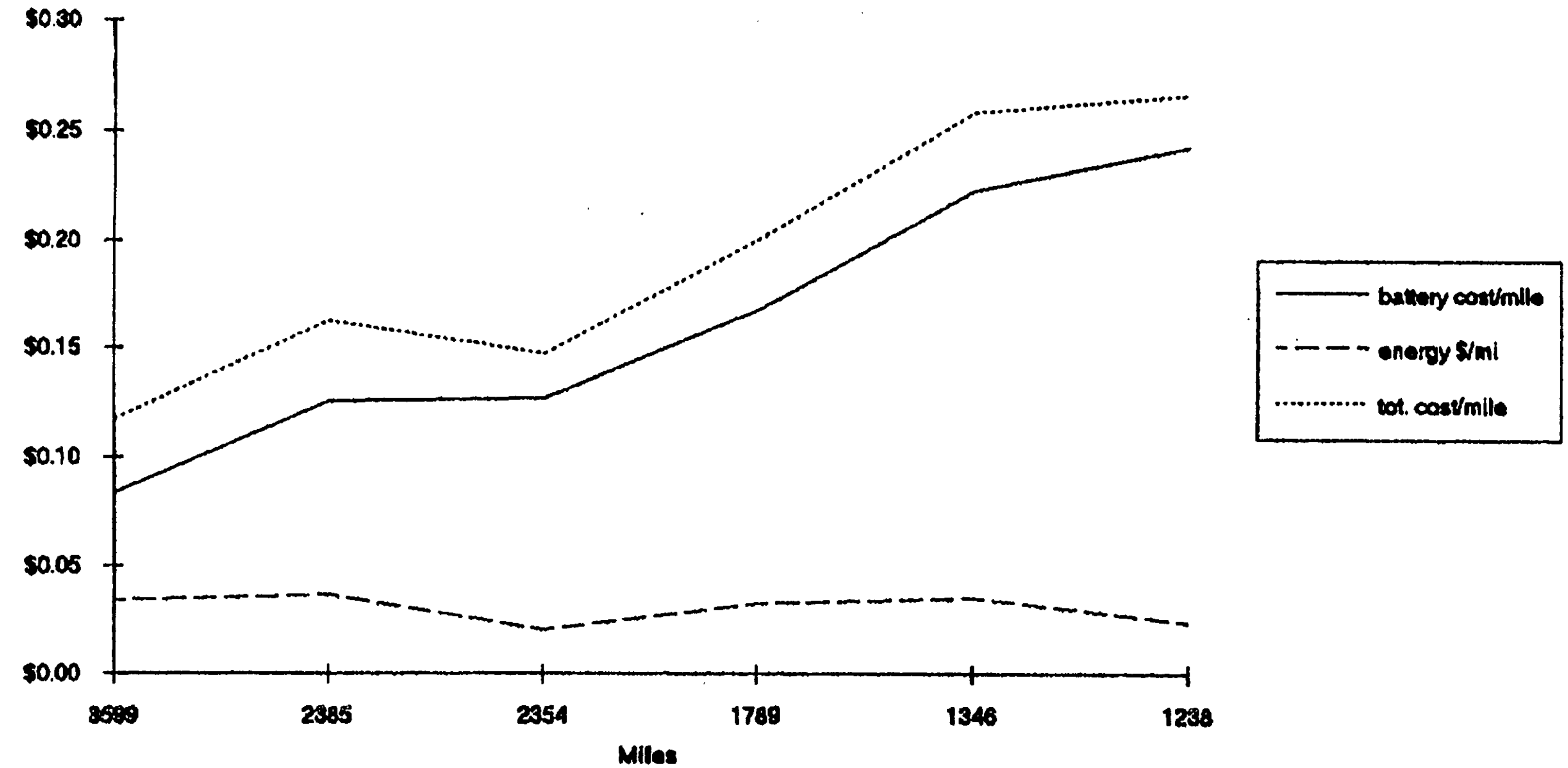
VIN	Operator	Battery Type	Battery Status	Days	DAS days	Cycles	Miles	Days Per Cycle	Miles Per Cycle	DOD	Discharge DC W-h	Charge AC W-h	Efficiency %
4030	MacDougal	Trojan	good	441	235	444	3599	0.99	8.11	34%	921	2758	33%
4147	Cartwright	GNB	failed	228	14	305	2354	0.75	7.72	23%	734	1552	47%
4032	Whitney	Trojan	failed	380	0	203	2385	1.87	11.75	49%	1312	4295	31%
4129	Townsend	Trojan	marginal	452	46	190	1789	2.38	9.42	37%	992	3055	32%
4144	Baer	GNB	failed	196	70	188	1238	1.04	6.59	21%	685	1581	43%
4126	Kuris	Trojan	failed	320	0	140	1346	2.29	9.61	40%	1074	3408	32%
4133	McClellan	Trojan	failed	378	0	85	201	4.45	2.36	10%	264	3314	8%
4143	Powers	GNB	good	124	111	48	202	2.58	4.21	19%	628	2585	24%
4142	McClellan	GNB	1 bat chg.	222	46	70	218	3.17	3.11	10%	320	1992	16%

Effect of Days per Cycle on City-el Battery Life



BA 7 XLS Chart 5

City-el: Energy and Battery Cost



5/1/95

Back-up Data

Available on Request

Document Title:	**Number of Pages:**
City-el DAS Analysis Assistant Program	12 Pages
Trojan Battery Specifications FAX	3 Pages
GNB Battery Specifications Sheet	1 Page
Trojan Batteries	
City-el 4030 Battery Data Summary	1 Page
City-el 4030 Manual Battery Data	1 Page
City-el 4030 DAS Data	11 Pages
City-el 4032 Battery Data Summary	1 Page
City-el 4032 Manual Battery Data	1 Page
City-el 4126 Battery Data Summary	1 Page
City-el 4126 Manual Battery Data	1 Page
City-el 4129 Battery Data Summary	1 Page
City-el 4129 Manual Battery Data	1 Page
City-el 4129 DAS Data	2 Pages
City-el 4133 Battery Data Summary	1 Page
City-el 4133 Manual Battery Data	1 Page
GNB Batteries	
City-el 4141 & 4143 Battery Data Summary	1 Page
City-el 4141 & 4143 Manual Battery Data	1 Page
City-el 4143 DAS Data	3 Pages
City-el 4142 Battery Data Summary	1 Page
City-el 4142 Manual Battery Data	1 Page
City-el 4142 DAS Data	2 Pages
City-el 4144 Battery Data Summary	1 Page
City-el 4144 Manual Battery Data	1 Page
City-el 4144 DAS Data	5 Pages
City-el 4147 Battery Data Summary	1 Page
City-el 4147 Manual Battery Data	1 Page
City-el 4147 DAS Data	1 Page
City-el 4147 Arthur Cartwright's Manual Data	11 Pages

Final Wiring of the Pepco Turbo-Z Charger to the City-el Electric Vehicle.

4 August, 1995

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

REPORT: Final Wiring of the Pepco Turbo-Z Charger to the City-el Electric Vehicle.
Prepared by: Lance Atkins, Pacific Electric Vehicles, 8-4-95

Background: As part of the ongoing component tests of the Neighborhood Electric Vehicle program, the Pepco Turbo-Z charger has been installed for long term use in one of the City-el vehicles. This vehicle is ID# 3999 and is in use at McClellan AFB by the U.S. Coast Guard. Two previous reports related to this charger are Test Report: PEPCO TURBO-Z CHARGER USE ON A City-el and Consequences and Wiring for Long Term Use of the Turbo-Z. These reports are the result of tests run on the Turbo-Z prior to this installation.

Scope: This report documents the final installation of the Turbo-Z charger. Wiring, safety considerations, and data collection are all described as well as the reasons behind the differences between this wiring and that described by the Consequences and Wiring for Long Term Use of the Turbo-Z report.

Conclusions: Installation of the Pepco Turbo-Z charger is complete. The system seems to work well and retains almost all of the systems in the City-el. All of the original charger safety features have been retained. Unfortunately, the capacity gage could not be entirely retained and the low voltage light is the only remaining capacity gage function. Safety warning labels and instruction labels have been placed in appropriate locations to notify users of operating changes. Data collection remains essentially the same except for the loss of Data Acquisition System (DAS) information on AC-Watt-hours and charging current. AC-Watt-hour information is available for the monthly manual data collection using the AC-Watt-hour meter supplied by Pepco. This test is being performed on a set of 3 new Trojan 30XHSAP batteries installed when the Turbo-Z charger installation was complete.

Wiring of Charger.

The charger has been installed inside the Coast Guard supply building where the vehicle is usually kept. It has been set on the floor nestled between some electrical conduits and distribution boxes located on one wall of the building. It has been plugged into the available 208 Volt service with a 30 amp breaker. The AC-Watt-hour meter has been installed in the line prior to the charger and is strapped to the top of the charger. The location is ideal for charging the vehicle and is out of the way.

The wiring of the vehicle is shown in the drawing Pepco Turbo-Z Charger and Capacity Gage Modifications Rev. 2. This drawing can be found in the appendix. The charger plug for the vehicle was enclosed in a box and fastened to the City-el in the same location

as the usual City-el transformer. Wires were then run as shown in the drawing. This installation is quite neat and easy to use. It should be noted that the original charger can no longer be used with this vehicle without changing the wiring.

During operation, the circuit performs the following tasks. Under driving conditions, the micro switch located next to the charge plug is open. In this condition, the relay is off. The drive circuit wire is closed, and the DAS through pin J7,7 is connected to 36 volts. When the charger is plugged into the vehicle, the micro switch closes. This turns on the relay which opens the drive circuit wire and connects the DAS to ground. When pin J7,7 is connected to ground not only does the DAS go into charge mode, but the charge light on the dash lights.

A review of the schematic will show several differences between this installation and the installation described in previous reports. Additional wiring was used to make the DAS record charges. Although the current and AC-Watt-hour readings don't work, the temperature and the voltage readings seem to work well. In addition, the dates and times of charges can be recorded. It can also be seen that the charge shunt has been bypassed. There are two reasons for this. First, although the original charge shunt would have worked with the capacity gage based on experience with other high rate chargers, the charge shunt "sings" and heats up quickly when used with the Turbo-Z. Second, although the originally specified 50mV / 25A charge shunt could have been installed, it would only provide the illusion of an operating capacity gage. For these reasons, the charge shunt and the capacity gage shut off have been bypassed. This leaves the vehicle with only the low voltage light for a capacity gage. A label has been placed in the vehicle to notify users of this fact.

Safety.

The wiring of the vehicle has maintained the drive lockout when charging. This will eliminate the possibility of the vehicle being driven away while the charger is still connected.

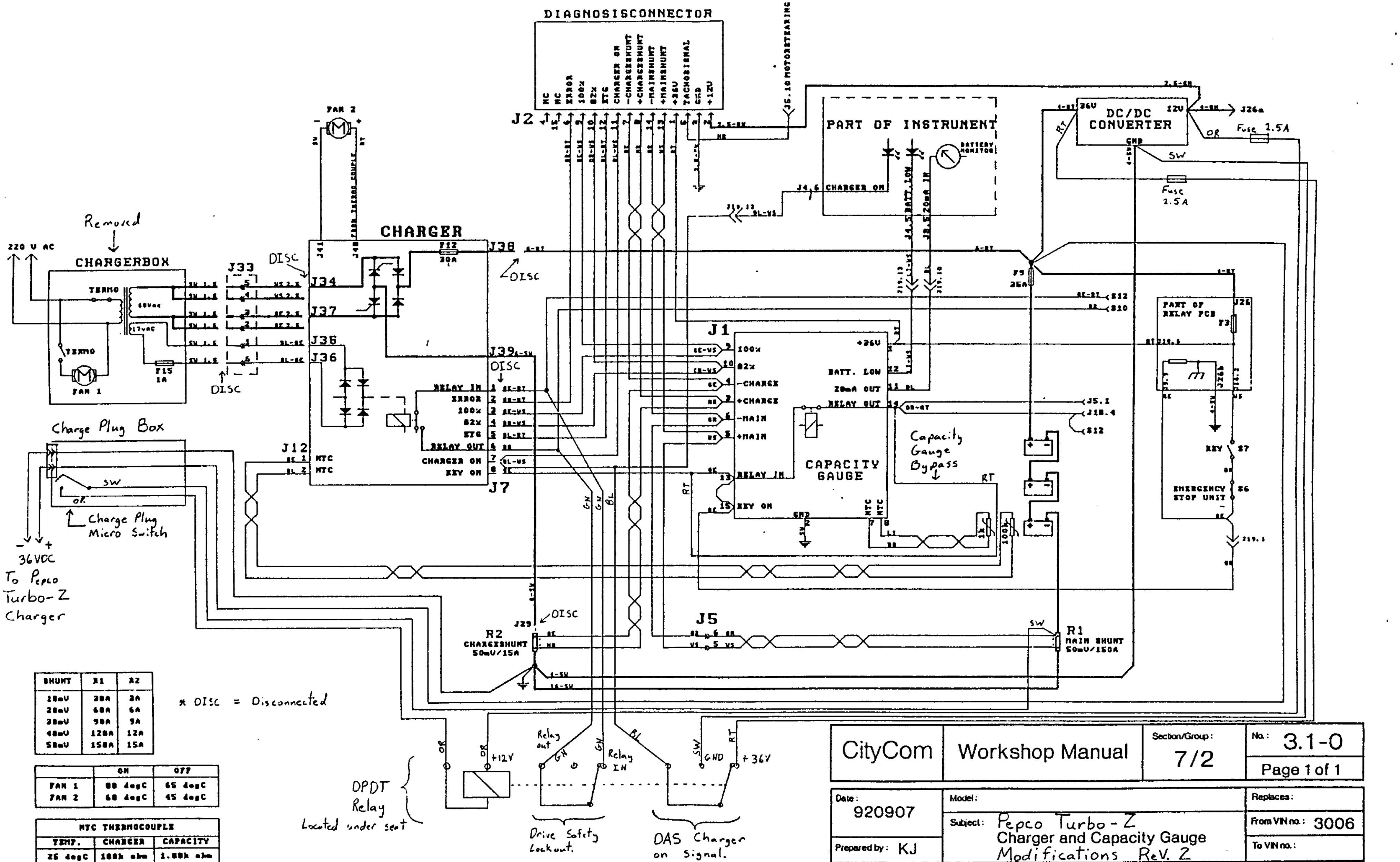
The charge plug box has been marked with a caution label indicating the presence of 36 VDC and the possibility of a shock hazard. This label as well as the other warning and information labels are included in the appendix. A label was also placed next to the old transformer plug indicating that it can no longer be used. The wiring is such, however, that should someone plug in a transformer no damage to the person, vehicle, or batteries should occur. A label indicating how to turn the charger off has been placed above the Turbo-Z "Station Advance" button. Finally, A copy of the Turbo-Z Owner's Manual was placed in the vehicle in addition to a short instruction sheet that was placed on the charger. A copy of this instruction sheet is included in the appendix.

Data Collection.

Only a few modifications are needed to the data collection routine for this vehicle. DAS data will not include AC-Watt-hour information or the charge current. AC-Watt-hour information is not available since the AC-Watt-hour meter does not have a signal that can

be sent to the DAS. Charge current data is not available because of a noise problem between the DAS and the Turbo-Z charger. In addition to the loss of the AC-Watt-hour readings and current readings on the DAS files, the AC-Watt-hour meter should be reset each month after recording the number of AC-Watt-hours used. Unfortunately, this reading is subject to errors. Should the charger be unplugged or the reset button pushed by users of the vehicle, the information will be lost. DO NOT UNPLUG CHARGER and DO NOT RESET METER labels have been placed appropriately to reduce this problem. The instruction sheet on the charger also asks for the user to notify Ron Coomes should the reset button get bumped. Finally, the batteries for this City-el have been replaced with 3 new Trojan 30XHSAP batteries. This should allow for battery life and performance comparisons between the Turbo-Z charger and the standard City-el charger.

APPENDIX



SHUNT	R1	R2
10mV	30A	3A
20mV	60A	6A
30mV	90A	9A
40mV	120A	12A
50mV	150A	15A

* DISC = Disconnected

	ON	OFF
FAN 1	80 degC	65 degC
FAN 2	60 degC	45 degC

NTC THERMOCOUPLE		
TEMP.	CHARGER	CAPACITY
25 degC	180k ohm	1.80k ohm
15 degC	[illegible]58k ohm	1.68k ohm
0 degC	340k ohm	3.40k ohm
-10 degC	585k ohm	5.85k ohm

CityCom	Workshop Manual	Section/Group: 7/2	No.: 3.1-0
			Page 1 of 1

Date: 920907	Model:	Replaces:
	Subject: Pepco Turbo-Z Charger and Capacity Gauge Modifications ReV. 2	From VIN no.: 3006
Prepared by: KJ		To VIN no.:

Modifications Drawn By: [illegible] Date: 8-4-95

Caution!
36 VDC

charge plug box Label

Shock Hazard!

Warning: Capacity Gage May No Longer Work Normally. Check Low Voltage Light Frequently.

capacity gage warning

DO NOT RESET METER! ⇒

AC-Watt-hour meter label

DO NOT UNPLUG CHARGER!

wall plug label

PRESS TO TURN CHARGER OFF. WAIT FOR RED LIGHT TO GO OUT.

"station Advance" button label

DO NOT USE ORIGINAL CHARGER.

old charger plug label

Pacific EV Phone: (916) 381-3509 FAX: (916) 381-2189

City-el Pepco Turbo-Z Charger Instructions.

To Charge:

1. Turn Off City-el.
2. Connect Charger to City-el.
3. Charger Will Turn On Within 60 Seconds.
4. Vehicle Is Charging While Red Light Is On.
5. Vehicle Is Charged After Green Light Comes On.
6. Unplug Vehicle Soon After Green Light Comes On.
7. **Recharge Vehicle At Least Every 4 or 5 Days Even If It Has Not Been Driven.**

To Turn Off Charger:

1. Press The "Station Advance" Button.
2. Wait for Red Light to Go Out.
3. Unplug Vehicle from Charger.

DO NOT UNPLUG VEHICLE FROM CHARGER WHILE CHARGER IS ON!

Other Notes:

1. Read Turbo-Z Owner's Manual for Complete Instructions.
2. If The Green Light is Blinking , Notify Ron Coomes at 643-5443.
3. DO NOT RESET Watt-hour Meter. If Reset Button Gets Bumped, Notify Ron Coomes at 643-5443.
4. DO NOT UNPLUG CHARGER FROM WALL!
5. The City-el Capacity Gage may no longer work normally with this charger. However, the vehicle will not shut off until after the low voltage light starts coming on. Even if there are no "Dots" on the capacity gage, the vehicle will run until after the low voltage light comes on. The low voltage light first comes on when pulling away from a stop. The light is located on the left side of the instrument panel. Charge the vehicle as soon as possible after this light comes on.
6. DO NOT TRY TO USE THE ORIGINAL CHARGER. IT HAS BEEN DISCONNECTED FROM THE BATTERIES.

Pacific EV

Phone: (916) 381-3509 FAX: (916) 381-2189

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FAX 707-468-1460

LOS ANGELES SALES OFFICE
1613 CHELSEA ROAD, SUITE 244
SAN MARINO, CA 91108
FAX: 818-289-5946

30 September, 1995

Sacramento Municipal Utility District
Electric Transportation Dept.
PO Box 15830 MS 30A
Sacramento, CA. 95852-1830

Attention: Mr. Steve Rutter

Subject: Prototype NEV Steering System Design Submittal

Reference: "Safety Characteristics, Peregrin NEV" document dated 6/8/95.

Dear Steve,

We have completed the steering system design for the Peregrin NEV. Enclosed are drawings of the Steering Column Assembly and the Front Suspension Assembly. Also enclosed are some details including the Steering Rack specification drawing, and the Steering Arm. Considerable effort has been made to provide accurate Akerman geometry, minimum bump steer through the travel of the front suspension, and to optimize driver feel through the steering system. I believe these design goals are met with this design.

Compliance with FMVSS 204, rearward steering displacement was discussed in the referenced Safety Characteristics document. Our design for compliance with FMVSS includes a collapsible steering column is rigidly mounted to the front bulkhead in the body-chassis structure. The multiple U-joint steering column is designed to collapse in front of this bulkhead, while the top of the steering column can collapse if contacted by the driver. All components are protected by the Body Chassis. There is sufficient space for airbag incorporation at a later date.

Akerman Geometry was derived by calculation and checked by layout through a couple of iterations. Steering arm length and steering rack ratio's available were juggled to arrive at the final design. The Peregrin is designed for a 16 ft turning radius, and should be able to turn inside a 32 ft diameter circle.

Lack of center feel was a problem with the four wheeled City-el's. Even the third unit with lower column friction, improved geometry, and a higher wheel angle change per unit steering wheel movement is still very light on steering effort, even though center feel is improved. Instead of increasing the caster angle for the Peregrin, some caster offset is incorporated in the steering king-pin to increase centering force. The caster angle remains 4 degrees as used on the "4 wheelers". The steering for the Peregrin is designed for minimum steering column friction, and needle bearing U-joints are specified. We expect a static steering effort at the steering wheel of about 3-4 lbs. The steering wheel can be turned 2.6 revolutions lock to lock.

The steering rack is located to minimize bump steer. Bump steer checks out by layout as less than 1/8" toe change throughout the loaded (upper) part of the 7" suspension travel.

We added a U-joint to the present Steering Column assembly compared to the general arrangement shown on the lay-out drawing handed over to you on 5/24/95. This is to allow more clearance to the master cylinders, and to decrease the operating angle of the upper U-Joint to reduce friction and stay within the manufacturer's specification for operating angle.

I trust this submittal is satisfactory. Enclosed is a copy of invoice SNEV 34 and a cost report. Please call me if there are questions.

Best regards,

Bill

W.R. Warf
Pacific EV

Prototype NEV Glazing Design

11 September, 1995

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

REPORT: Prototype NEV Glazing Design.
Prepared by: Lance Atkins, Pacific Electric Vehicles, 9-11-95

Scope.

This report covers the glazing design details for all of the windows in the Pacific Electric Vehicles Prototype NEV here after called the Peregrin. Following the Summary, there are four major sections to this report. Three of the sections cover each individual window. Requirements from Federal Motor Vehicle Safety Standard 205 (FMVSS 205) are discussed for each piece of glazing as well as glazing material choice based on these requirements. Installation methods for each window are also described. Alternatives and possible changes for pre-production design are discussed where applicable. Since both the side windows and the rear window will be fabricated from rigid plastics, a fourth section gives the FMVSS 205 requirements for both of these windows.

Background.

The Peregrin is being designed exclusively around an electric powertrain. In addition, it is designed primarily for short trips around the neighborhood or for short commutes to work in urban settings. Because of this, weight reduction is one of the most important design considerations. The stop-and-go use that the vehicle will undergo causes a large percentage of the available energy to be used accelerating the vehicle. In order to reduce the amount of energy used during acceleration and increase the range of the vehicle, it is necessary to reduce the overall mass of the vehicle. For this reason, it is desirable to look at glazing options other than glass. Rigid plastics have been increasingly used for various automotive applications. Advances in material compositions and coating technologies have made available plastics that can provide not only the needed clarity for windows but also the needed wear resistance and safety. Fortunately, these plastics provide all of these features while providing a significant weight savings over glass. For this reason, the Peregrin will use rigid plastic glazing in all locations allowed by FMVSS 205.

Summary.

FMVSS 205 leaves little room to pick anything other than safety glass for the windshield. For this reason, the windshield will be a Honda 600 sedan windshield. This window meets the FMVSS 205 requirements. It will be installed by bonding it to the chassis with an automotive glazing adhesive. Production vehicles will use this same window and installation method.

For removable side windows like the Peregrin will have, FMVSS 205 allows the use of Item 4 rigid plastic glazing materials. This material is described in American National Standards Institute standard Z26.1 (ANSI Z26.1). The prototype side windows will be fabricated from GE LEXAN MR5 polycarbonate sheet. This material should pass most of the tests required by FMVSS 205. Only the weathering test might cause problems. Depending on the results of the tests, production vehicles might need to have the glazing material changed to a different coated polycarbonate or to a silica-filled organo-

polysiloxane coated acrylic-imide copolymer like that used in 1983 and later Corvette sun roofs. The windows will be installed by fastening the glazing to a "window brace" which is then installed in the window frame of the door using locating pins and 1/4 turn Dzus fasteners. A Trim-LOK seal placed around the edge of the window opening will provide weather tightness. No change in this installation method is anticipated for the production vehicles.

The Peregrin will have a removable rear window so that the rear luggage compartment can be used as a small utility bed. Since FMVSS 205 allows the use of Item 4 rigid plastics for removable windows and rear windows of convertible tops, it appears that this material can be used for the rear window. An aircraft grade cell-cast acrylic will be used for the prototype rear window. The acrylic will be coated with a silica-filled organo-polysiloxane coating to improve abrasion resistance. It will have better optical properties than the LEXAN MR5 used for the side windows and should pass the FMVSS 205 requirements except for possibly the impact tests. This window and the side windows will be compared to assess the performance differences between coated polycarbonates and coated acrylics. Production vehicles may use either a coated polycarbonate or a coated acrylic-imide copolymer for the rear window. The rear window will be installed using external automotive hinges and will be lifted using automotive type lift struts. The latch will be an automotive finger latch with a locking push button. Production vehicles may have a frame placed around the window. Sealing will be provided by a Trim-LOK seal placed around the edge of the opening for the rear window.

It is anticipated that the final pre-production glazing choices for all of the windows will comply with FMVSS 205 requirements.

1.0 Windshield.

<u>1.1 Requirements.</u> FMVSS 205 specifies that all glazing materials shall conform to the American National Standards Institute standard "Safety Code for Safety Glazing Materials for Glazing Motor Vehicles and Motor Vehicle Equipment Operating on Land Highways." This standard is also known as ANSI Z26.1. FMVSS 205 does provide some exceptions to ANSI Z26.1, but in the case of the windshield, there are no exceptions. Only Item 1 materials are specified "for Use Anywhere in [a] Motor Vehicle." This means that the windshield must be fabricated of a material that meets all of the tests specified in Item 1.

ANSI Z26.1 Item 1 required tests are as follows.

Test 1: <u>Light Stability.</u> Samples of the material shall be subjected to 100 hours of ultraviolet radiation from a Uviarc test cabinet, 220-volt Cooper Hewitt laboratory outfit or the equivalent. After irradiation the samples "shall retain at least 70% of the original transmittance."

Test 2: <u>Luminous Transmittance.</u> The material weathered in test 1 "shall show regular (parallel) luminous transmittance of not less than 70% of the light, at normal incidence, both before and after irradiation."

Test 3: Humidity. Specimens shall show no separation of materials except for occasional small spots around the edge after remaining in a closed container with water for 2 weeks at a temperature of 125 °F.

Test 4: Boil. Specimens shall be vertically immersed in boiling water for 2 hours. After removal the specimens will have no defects other than small separations and cracks at the very edge of the material.

Test 9: Dart Drop Impact Test 30 ft. A 7-ounce steel dart shaped as specified shall be dropped from 30 ft. The glass may crack or be punctured, but the puncture shall be smaller than the body of the dart and no pieces of glass may become disengaged other than small pieces located at the puncture site.

Test 12: Ball Drop Impact Test 30 ft. A 1/2 pound steel ball shall be dropped from 30 ft. The glass may crack or be punctured, but no hole or crack shall be large enough for the ball to pass through and no pieces of glass shall become disengaged other than small pieces located at the puncture site.

Test 15: Optical Deviation and Visibility Distortion. Minimal shifts in secondary images generated during testing is allowed. Minimal light and dark patches shall exist during the testing.

Test 18: Abrasion Resistance (Safety Glass). A Taber Abraser according to ASTM D 1044-82 should be used. The abrasive wheel should be a Calibrase CS-10F-81 or equivalent with a durometer hardness according to ASTM D 2240-81 (72 ±5). Haze is to be measured with "an integrating sphere, photoelectric photometer" according to ASTM D 1003-61. After 1000 cycles the average amount of light scattered due to abrasion shall not exceed 2%.

Test 26: Penetration Resistance. A 5-lb steel ball shall be dropped from 12 ft. After impact the ball shall not pass through the sample during the 5 second interval after impact.

Marking requirements of Safety Glazing Materials are also specified in ANSI Z26.1. Each piece is to be marked with the words American National Standard or AS, the manufacturer's model number and trademark, and a numeral for which Item number the material complies with. In the case of the windshield, this would be the number "1" for Item 1.

1.2 Materials. Since safety glass fulfills the above requirements, it will be used for both the prototype and for production vehicles. The prototype will use a windshield from a Honda 600 sedan. This window comes from a production vehicle and as such is expected to comply with the requirements of FMVSS 205 and ANSI Z26.1. Production vehicles will use this same window supplied from an automotive glazing manufacturer.

<u>1.3 Installation.</u> The windshield will be installed by bonding it to the composite chassis using an automotive glazing adhesive. For the Prototype, an adhesive with a strength of 50 to 100 psi will be used. This should be sufficient to retain the window during a 60g impact. Final adhesive specifications for production vehicles will be made after experimentation with the prototype. Glue strength needs, surface preparation procedures, and application procedures will be tested at that time.

2.0 Rigid Plastic Glazing Requirements

The use of rigid plastics for automotive glazing is covered under Federal Motor Vehicle Safety Standard No. 205 which specifies American National Standards Institute Standard Z26.1 (ANSI Z26.1). Rigid plastics are covered under ANSI Z26.1 Item 4. However, FMVSS 205 modifies test 19 of ANSI Z26.1 to include 1) one percent solutions of nonabrasive soap, 2) Kerosene, 3) Undiluted denatured alcohol, formula SD No. 30 and, 4) Gasoline ASTM Reference Fuel C.

ANSI Z26.1 Item 4 applies to rigid plastics and requires the following tests.

Test 2: <u>Luminous Transmittance.</u> The material weathered in test 16 "shall show regular (parallel) luminous transmittance of not less than 70% of the light, at normal incidence, both before and after irradiation."

Test 10: <u>Dart Drop Impact Test Table 2 Heights.</u> A 7-ounce steel dart shaped as specified shall be dropped from the Table 2 Height (Table based on material thickness). The material may crack, but not more than one of the 5 specimens can break into large pieces.

Test 13: <u>Ball Drop Impact Test Table 2 Heights.</u> A 1/2 pound steel ball shall be dropped from the Table 2 Height (Table based on material thickness). The material may crack, but not more than two of the 5 specimens can break into large pieces. Further, not more than two pieces can fracture so as to leave a hole.

Test 16: <u>Weathering.</u> Material shall be tested using the procedure specified in ASTM D 1499-64 and ASTM G 23-81. The material is to be subjected to 1000 hours of carbon arc and water spray. "The decrease in regular (parallel) luminous transmittance of the irradiated specimens shall not exceed 5%."

Test 17: <u>Abrasion Resistance (Plastics).</u> A Taber Abraser according to ASTM D 1044-82 should be used. The abrasive wheel should be a Calibrase CS-10F-81 or equivalent with a durometer hardness according to ASTM D 2240-81 (72 ±5). Haze is to be measured with "an integrating sphere, photoelectric photometer" according to ASTM D 1003-61. After 100 cycles the average amount of light scattered due to abrasion shall not exceed 15%.

Test 19: Chemical Resistance Nonstressed. Using the chemicals listed in FMVSS 205 for test 19, "There shall be no tackiness, crazing, or apparent loss of transparency..." after 1 minute of immersion.

Test 20: Chemical Resistance Stressed. This is the same as test 19 except that the plastic shall be under a tension stress of 1000 psi on the surface. The same results are required.

Test 21: Dimensional Stability. Material will be subjected to 160°F (71°C) and 70% to 75% relative humidity for 24 hours warpage should not exceed 0.050 in.

Test 24: Flammability. "The horizontal burning rate shall not exceed 3.5 in/min (1.48 mm/s)."

Just like the safety glass, rigid plastics have marking requirements specified in ANSI Z26.1. Each piece is to be marked with the words American National Standard or AS, the manufacturer's model number and trademark, and a numeral for which Item number the material complies with. In the case of rigid plastics, this would be the number "4" for Item 4.

3.0 Side Windows

3.1 Requirements. All of the FMVSS 205 requirements listed in section 2.0 of this report apply to the side windows of the Peregrin. ANSI Z26.1 lists specific locations where Item 4 rigid plastics can be used. One of those listed locations is "Flexible curtains or readily removable windows..." Since the Peregrin will have removable side curtains for the side windows, Item 4 rigid plastics can be used.

3.2 Materials. For the Peregrin, the side windows will be fabricated from GE's LEXAN MR5 UV and Mar-Resistant Glazing. Material 1/8" thick will be used. This material is expected to meet all of the following requirements:

- Initial Luminous Transmittance.
- Dart Drop Impact Test.
- Ball Drop Impact Test.
- Abrasion Resistance.
- Chemical Resistance Nonstressed.
- Chemical Resistance Stressed.
- Flammability.

It is not clear whether it will meet the following requirements:

- Post Weathering Luminous Transmittance.
- Weathering.
- Dimensional Stability

Since the LEXAN MR5 is being used on the City-el canopy top replacements, some idea of the weatherability will soon be available. The windows for the Peregrin will not meet the labeling requirement. Production vehicles though will meet these requirements.

If it is found that the LEXAN MR5 does not meet the weathering requirements, there are two possible changes for the production vehicles. Another type of polycarbonate sheet similar to LEXAN could be coated with a silica-filled organo-polysiloxane coating like those offered by SDC Coatings. Coatings of this type have been used on automotive polycarbonate headlight-covers for a few years now. This coating system might provide better performance than the coating system used on the LEXAN MR5. If this doesn't work, it might be necessary to switch from polycarbonate to an acrylic in order to get the required weatherability. Although the acrylic is not as tough as the polycarbonate, it has better luminous transmittance, abrasion resistance, and weatherability than polycarbonate does. General Motors has used an acrylic-imide copolymer coated with a silica-filled organo-polysiloxane coating for the Corvette sunroof since 1983. This systems seems to have worked well in that application and would be expected to provide excellent performance if used for the side windows. It may, however, be necessary to change the material thickness if the acrylic-imide copolymer is used.

3.3 Installation. The sketch "Side Window Installation, Peregrin" is included in the appendix. For this installation, a flat cutout for the side window will be fastened to a "window brace." This window brace will give the window enough rigidity to maintain it's location and prevent unauthorized entry to the vehicle even though only a few attachment points are used. A minimal number of attachment points is desirable in order to ease the removal and installation of the side window. The upper attachment points are locating pins that attach to the window brace and insert into holes located in the window frame of the door. The lower attachment points are quarter turn Dzus fasteners with a ring style head. These fasteners are retained in the window brace and have ejection springs to aid in the removal and installation of the window. Receptacles for the Dzus fasteners will be located in the window frame.

During use, installation of the window will require the upper locating pins to be started in the holes at the top of the window frame. As these pins are inserted, the lower portion of the window can be swung into place. Once this is complete the 1/4 turn Dzus fasteners can be pushed in and turned. Removal of the window will follow the exact opposite of this procedure.

The window seal will be provided by a Trim-LOK Rubber-LOK 1100-1/8" seal installed around the edge of the window opening. This seal should provide adequate sealing and will provide a nice finished surface around the window opening when the window is removed.

Currently there are no anticipated changes for the production vehicles. Any refinements to the design or changes in seal type or location will have to be considered after evaluation of the current design.

4.0 Rear Window

4.1 Requirements. Since the rear window will be fabricated from rigid plastics, the FMVSS 205 requirements listed in section 2.0 of this report apply. Although ANSI Z26.1 does not explicitly allow Item 4 rigid plastics to be used for this type of application,

it appears that this use is allowed. Item 4 materials are explicitly allowed for "Flexible curtains or readily removable windows.." and "The rear windows of convertible passenger car tops." Although the Peregrin does not have a traditional convertible top, the rear window will be readily removable in order for the rear luggage compartment of the vehicle to be used as a small utility bed. Based on this, it seems like the use of Item 4 rigid plastics for the rear window is consistent with the standard.

4.2 Materials. For the Peregrin, an aircraft grade cell-cast acrylic 3/16" thick will be used for the rear window. The window will also be coated on both sides with a silica-filled organo-polysiloxane based coating. This material and coating is expected to meet all of the following requirements.

- Initial Luminous Transmittance.
- Post Weathering Luminous Transmittance.
- Weathering.
- Abrasion Resistance.
- Flammability.
- Chemical Resistance Nonstressed.
- Chemical Resistance Stressed.
- Dimensional Stability

It is unknown at this time whether it will meet the following requirements.

- Dart Drop Impact Test.
- Ball Drop Impact Test.

For the prototype, this window will not be marked as required. On production vehicles all requirements will be met.

A coated acrylic has been chosen for several reasons. First, it will provide a weathering and abrasion resistance performance comparison with the LEXAN MR5 used for the side windows. This should provide valuable information should either system fail to meet one or more of the requirements. Second, the increased rigidity of the acrylic may allow the window to be installed with no surrounding frame. Third, fabrication of an acrylic window is somewhat easier than a polycarbonate window, and finally, the quality of the acrylic window is slightly more predictable than that of the polycarbonate.

Three possible rear window options exist for the production vehicles. If everything tests out well with the coated acrylic, it may be retained in the production vehicles. Depending on the performance of the LEXAN MR5, the rear window may be changed to a coated polycarbonate. This would make fabrication slightly more difficult and would require the addition of a frame around the window, but the virtual elimination of safety hazards due to fracturing might be worthwhile. Lastly, it could be changed to a silica-filled organo-polysiloxane coated acrylic-imide copolymer. This material was mentioned earlier as a potential candidate for the side windows as well. The increased rigidity and service temperature of this material would be a particularly important improvement for the rear window. Results from the prototype windows will be needed before a final decision is made.

4.3 Installation. The sketch "Rear Window Installation, Peregrin" has been included in the appendix. The prototype rear window will be formed using a plug drawing technique. This technique has been used to make short production runs of aircraft canopies. It would be appropriate for production levels as high has 1000 units per year. Beyond this level, other higher production techniques like casting may be more viable.

The window will be attached to the vehicle using two external automotive type hinges similar to those used on the older Mazda RX7's and some of the classic British auto's. The hinge will be mounted to the window using a backing plate and low profile nuts over the hinge studs. An appropriate cover will be used to cover the exposed nuts and bolts. A thin seal will be used between the window and the hinge to prevent water leaks. The hinge will be attached to the body of the vehicle in a similar manner except that the mounting bracket for the lift strut will serve as the backing plate for the hinge mount. Wing nuts will probably be used to facilitate removal of the rear window. The window-side mounting bracket for the lift strut will be mounted to the window using two carriage bolts. A sealant will be used to seal the holes for the bolts. The lift struts will be similar to those used in other vehicles with hatchbacks. The latch will be an automotive finger latch with a locking push button. This type of latch can be seen on classic British auto's. The latch will engage a wire loop attached to the body. The edge of the body located under the window will be covered with a Trim-LOK Rubber-LOK 1100-1/8" seal to seal the interface between the window and the body. This completes the installation of the rear window.

Depending on how well the prototype window works, it may become necessary to place the rear window in a frame for production vehicles. The frame would enhance the rigidity of the window and improve the sealing of the window when closed. Production vehicles might also use a more traditional trunk type latching mechanism with the key hole located on the panel between the taillights. While these features would lend a more traditional automotive feeling to the vehicle, they increase the complexity and cost of the vehicle. Because of this, the prototype will be built without these features in order to assess the performance of the simpler method.

APPENDIX

Order of Appendix Contents:	Pages and Designation:
Sketch; Side Window Installation, Peregrin	1 page Drawing
Sketch; Rear Window Installation, Peregrin	1 page Drawing

PACIFIC ELECTRIC VEHICLES

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LOS ANGELES SALES OFFICE
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SAN MARINO, CA 91108
FAX: 818-289-5946

7 November, 1995

Sacramento Municipal Utility District
Electric Transportation Dept.
PO Box 15830 MS 601
Sacramento, CA. 95852-1830

Attention: Mr. Steve Rutter

Subject: Brake System Design submittal, NEV Prototype

Reference: Participation Agreement F-102

Dear Steve,

In accordance with the referenced Participation Agreement we are pleased to submit the following brief report regarding the brake system design for the Peregrin NEV Prototype. We have made an effort to design the brakes using readily available components and to meet low un-sprung weight goals for the Peregrin. Low un-sprung weight is important to allow a comfortable ride in the vehicle, as well as to provide good handling and minimum energy use. Locating components to be used on a four wheeled vehicle in this weight category is difficult, since there are few vehicles which are comparable in the US market.

The braking system is designed around motorcycle calipers and brake rotors. The Calipers are from Suzuki 600 Katana, while rotors are from Harley Davidson. The installation is substantially identical front and rear, and is shown on the Front Suspension Assembly Layout, and the Rear Suspension Assembly Layout, which are included in this submittal package.

Dual Master Cylinders are used to provide redundant front and rear brake circuits. Girling units with a 0.625" bore are attached to an after market pedal assembly, which is bolted into the composite structure as shown on the General Arrangement Layout handed over to you on May 24, 1995. The pedal assembly and mounting are capable of a 400 lb force applied to the pedal without undue flexing.

The hydraulic system is shown schematically on SK-103, also part of this submittal. The schematic also shows all component parts of the hydraulic plumbing, including a pressure switch to actuate the brake lights. It is noted that the brake lights are also actuated by the drive system when in regenerative braking mode.

We expect this braking system to allow a peak braking capability in excess of the adhesion of the tires. Calculations done to estimate the braking deceleration predict a deceleration of 8 m/s^2 with a 40 lb pedal force, and a system pressure of 363 psi. Actual deceleration values will need to be confirmed by testing. The system should be capable of braking distances according to FMVSS 105.

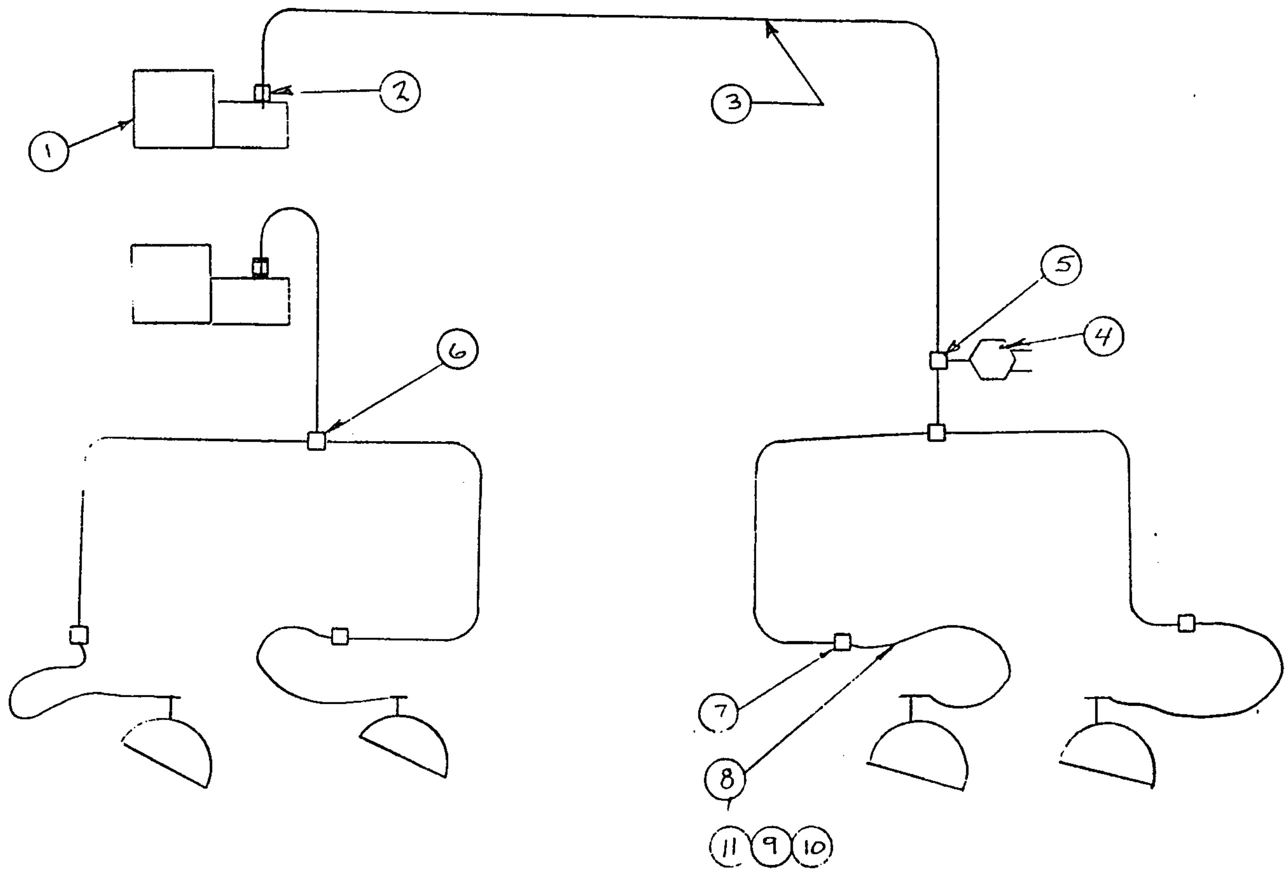
The design also includes a separate rotor for a parking brake with a mechanical caliper. This will provide a parking brake for the prototype which should meet the requirements of the FMVSS. This parking brake is shown on the Rear Suspension Assembly Layout.

We are pleased with the design of the braking system, and are looking forward to testing it. I trust this submittal meets with your approval. A copy of SNEV 38 and a cost report are attached. Should you have questions or comments please call me.

Best Regards,

Bill

W.R. Warf
Pacific EV



ITEM	DESCRIPTION	Qty.
1	GIRLING MASTER CYL 5/8" bore	2
2.	Adapter, Pegasus P/N 3265-12 3AN → -3F inverted flare,	2
3.	3/16 Steel brake tubing	A/R
4.	Brake Sw. Pegasus P/N 3601 1/8 NPT	1
5.	Female Branch Tee Weatherhead P/N 652X3	1
6.	UNION Tee Weatherhead P/N 702X3	2
7.	Adapter - UNION -3 inverted Flare to M10-1.0 Taper fitting Weatherhead P/N 1442F	4
8.	Brake hose, Citycom P/N 40.040 OR EQUAL	4
9.	BANJO BOLT	4
10.	Copper Crush [illegible] Pegasus P/N 3241-[illegible]	10
11.	Caliper	ref.

Peregrin
Prototype Brake [illegible] Schematic

SK 103

Pacific Electric Vehicles

W.R. [illegible]
11/7/95

PACIFIC ELECTRIC VEHICLES

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6 November, 1995

Sacramento Municipal Utility District
Electric Transportation Dept.
PO Box 15830 MS 601
Sacramento, CA. 95852-1830

Attention: Mr. Steve Rutter

Subject: NEV Prototype Suspension Design

Reference: Participation Agreement F-102

Dear Steve,

We have completed the design of the front and rear suspension systems for the Peregrin NEV Prototype. The design provides low unsprung weight and long suspension travel. Low unsprung weight is important for good ride and handling, while long suspension travel will allow a payload of up to 250 kg or 35% of the GAVWR without unduly harsh springs. The intent is for the suspension to take up the bumps without upsetting the passengers, and retaining maximum tire contact with the road.

This submittal includes assembly layout drawings for front and rear systems, along with detail drawings of upper and lower arms, trailing links, hubs, uprights, and other suspension components. Some of the front suspension components have been released for fabrication, and a few are complete.

This design employs the same method of suspension attachment to the composite chassis as was prototyped on the 4 wheeled City-el's. The present front suspension is an evolution of what we have learned from testing of the "4 wheelers". The front suspension employs the same Upper A Arm, and other parts are shared.

During the design process, stress and deflection analysis was performed to verify the strength of the components. The loading used was reasonably well defined in the Body Chassis Design Document. Maximum Design Load applied at the tire is 1878 Lbs for the rear, and 1764 lbs at the front. The wheel load to bottom the rear spring is 950 lbs, and the wheel load to bottom the front spring is 507 lbs.

The rear suspension will at first utilize a spring which limits rear suspension travel to 6.6", although 8" travel is possible given the stroke of the shock absorber. A special spring would have to be made to allow more travel, and some physical verification of the desired spring rate is in order first. If high angle constant velocity joints were used for the drive shaft, longer shocks and springs could be used to allow up to 9" of rear wheel travel. The front suspension travel is 7".

The Carrera shock and springs used have the advantage of adjustable spring platforms. They also have adjustable damping, and lots of stock springs to choose from. With this prototype design, springs are easy to change. These shocks have an aluminum body for low weight. Lower cost units can be substituted once final ride height, spring rate, and damping requirements are verified.

Both front and rear suspension geometry are designed to minimize bump steer. The expected bump steer on the Peregrin should be about 1/4" through the working suspension travel, compared to about 1/2" on the four wheeled City-el.

This suspension design is expected to provide a comfortable ride as well as a high payload. The design is appropriately light and strong for a light EV designed for a smaller, relatively inexpensive battery pack. A copy of invoice SNEV37 and a cost report are attached. Please call me if questions arise.

Best Regards,

Bill

W.R. Warf
Pacific EV

Zivan K05 36V Battery Charger Test Report

5 November, 1996

Neighborhood Electric Vehicle Product Test & Development Project

Prepared by: William R. Warf
Pacific Electric Vehicles

This Project is sponsored by DARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

Zivan K05 36V Battery Charger Test Report

Scope: This report provides a summary of testing performed on a Zivan battery charger installed on a City-el electric vehicle. Observations, notes on adjustment, and test results are provided.

Conclusions: The Zivan charger is a very light weight, economical charger. The charger we tested is capable of 860 W output, weighs 2kg, and cost $396 plus freight in 1995. Specific cost is about $0.5 per Watt, and specific power is more than 400W/kg. The charger gave a charging speed of 8-9 miles per hour as installed on the City-el, compared to 5-6 miles per hour for the OEM charger. The Zivan is adjustable for rate, gassing voltage, and finish current through the use of trimmer potentiometers, and so is adjustable for different batteries, or as the batteries age.

The Zivan does not exhibit the finish charge control of the City-el or American Monarch chargers, however these are in the $0.80-$1.20 per Watt cost range, and offer 50W/kg specific power. Although equipped with a temperature sensor, the effect of the sensor on the Zivan's charge algorithm has not been observed in the charging data obtained to date.

The Zivan charger is a good on board charger, as it gives a high rate bulk charge and doesn't weigh much. We obtained a K2 for this use for the Peregrin NEV Prototype. We may use a pair of City-el chargers off board the Peregrin for occasional equalizing of the pack if needed.

Testing Overview.

The charger was installed in City-el VIN...4152 on June 28, 1995. Data was collected as part of the NEV project through September, 1995. DAS data through April 96 is being provided with this report. Selected trips and charges have been printed out, and are attached and described in the following. Note the charger uses a 220 V service, and AC Watt Hours were not recorded because no instrument was available.

Initially the charger was used with a set of used SCS225 Trojan flooded batteries. The charges recorded on 6/28/95 and 7/12/95 show these batteries were heating up during the bulk charge to 50-60C. Notice also the charger was initially set with a float charge of zero. On 8/10/95, a new set of Trojan 30XHS batteries were installed, and the charger adjusted.

The City-el was driven over a consistent trip from my house to the shop and back. This trip is 10.7 km each way. It is downhill on the way to the shop, and slightly lower energy use is seen. A sample trip records is included in the attached data, as generated by BOXANA1.XLS.

Charge records for September through March show the typical charge received. Note these charge records are hourly averages, and only generally indicate the charge algorithm.

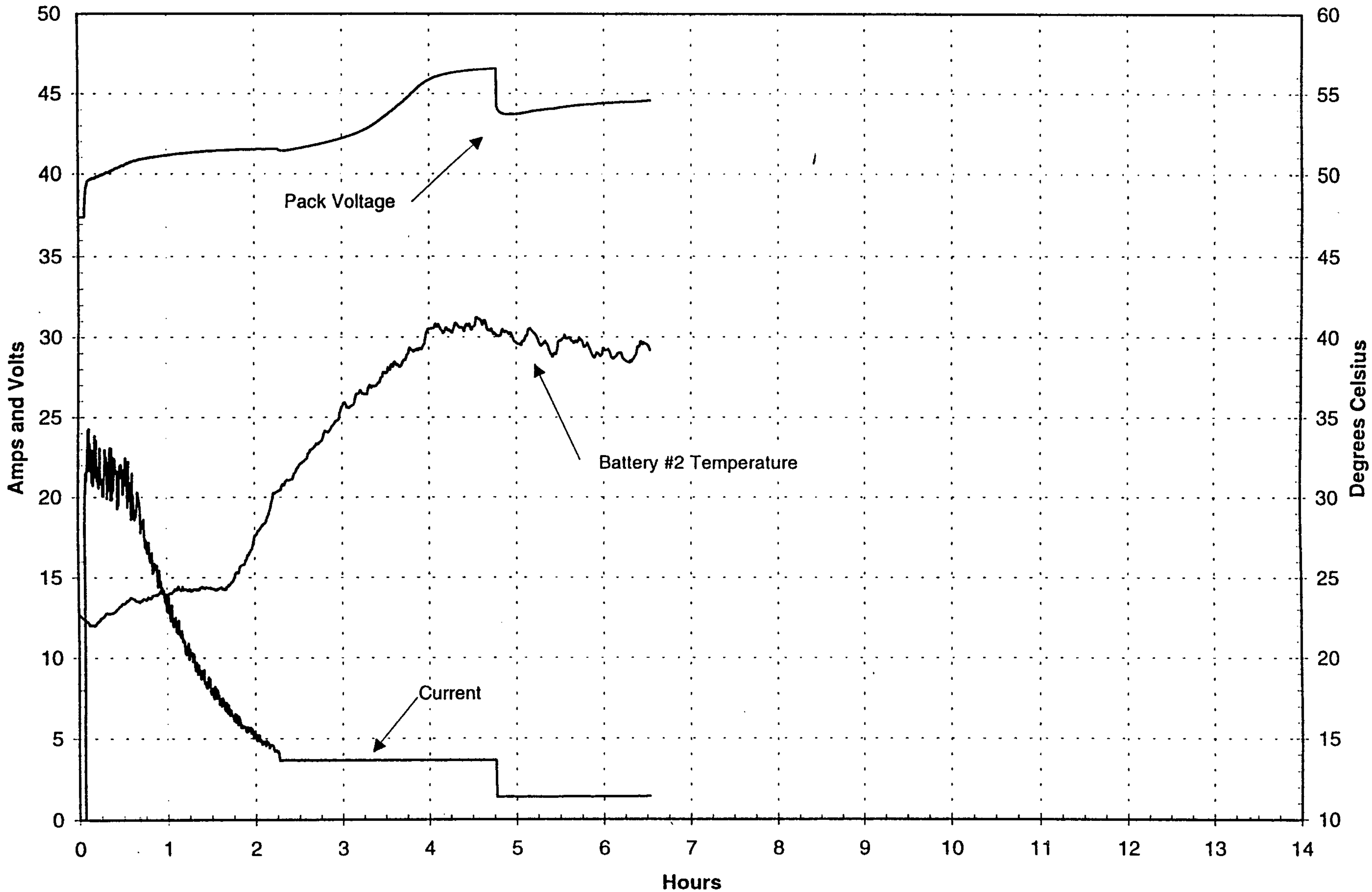
Charge Algorithm Description.
The Zivan is set up as an IUI charger, with an adjustable float voltage. This is a Constant Current, Constant Voltage, Constant Current algorithm. The charger comes on and provides a constant 22 Amps until a Voltage threshold is reached. The charger then tapers the current, while holding the voltage "constant". Finally a finish Constant Current region is reached, and the voltage released, while a current of about 3.5 Amps is provided. This portion of the charge lasts 2.5 hours, and the charger switches to a final constant current float charge, and the voltage remains uncontrolled.

This charge profile was recorded with a Fluke Hydra while testing on City-el 4126 at McClellan in early October 1996. The charge records are provided on the following pages. The charge recorded with the Hydra shows roughly the same signature as the City-el DAS data recorded on VIN-4152.

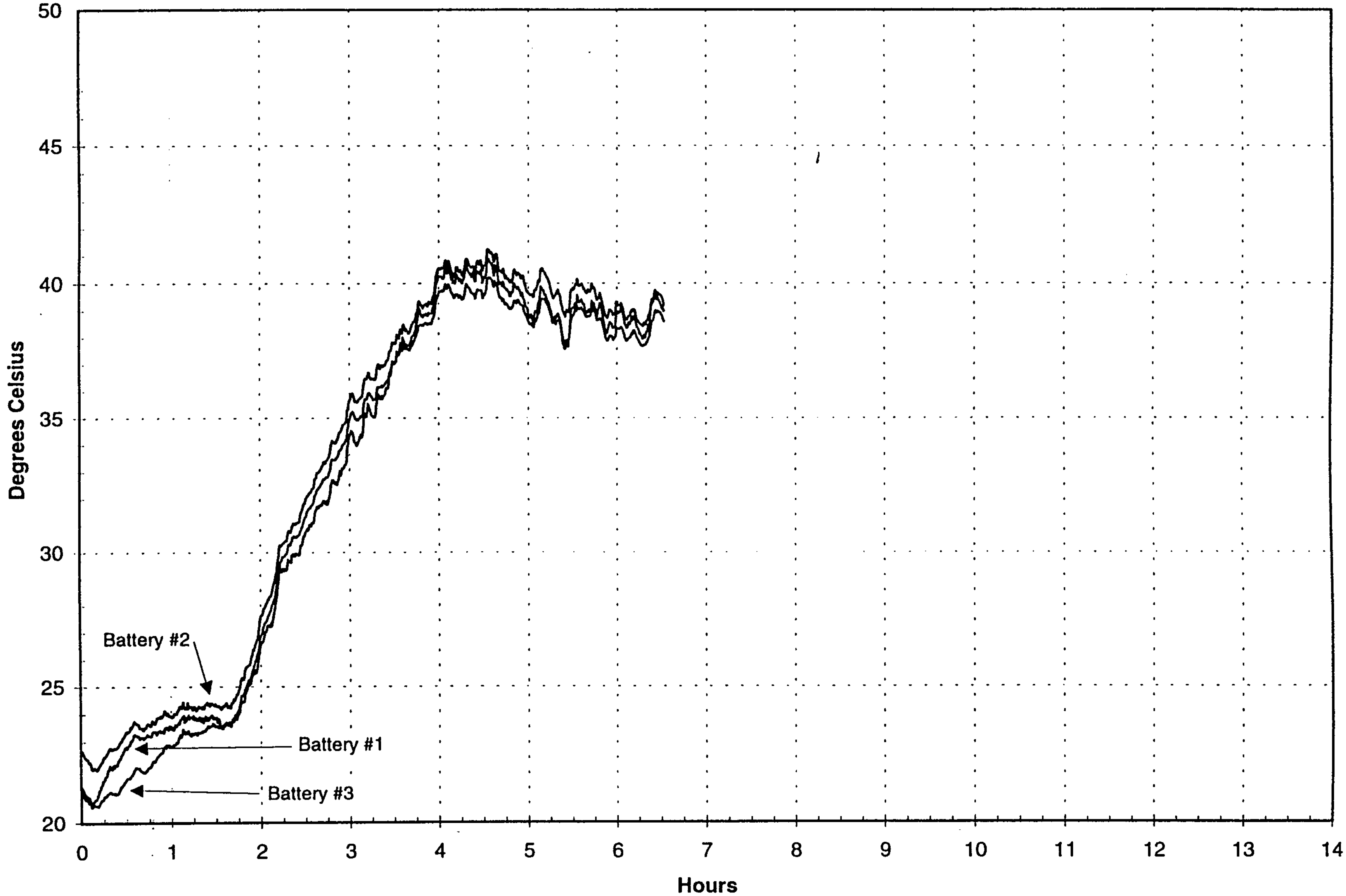
Test Results:
Shortly after installing the new batteries in August 95, the Zivan Charger appeared to be undercharging the batteries somewhat, and the float current was turned up to 1.5 A at that time. This provided some additional equalizing, however we had to remember to unplug the vehicle to minimize water use. The voltage continued to rise during the float, as shown in the DAS data.

Although provided with a Temperature Sensor, neither the first constant voltage phase, nor the float phase are temperature compensated according to the usual relation which is (for flooded batteries) $V=n*(2.6 -.0054(T-30C))$. where n is the number of Cells, and T is the temperature in degrees C. The City-el charger is temperature compensated, and the constant voltage phases follow the above relation, adjusting the constant voltage level as the

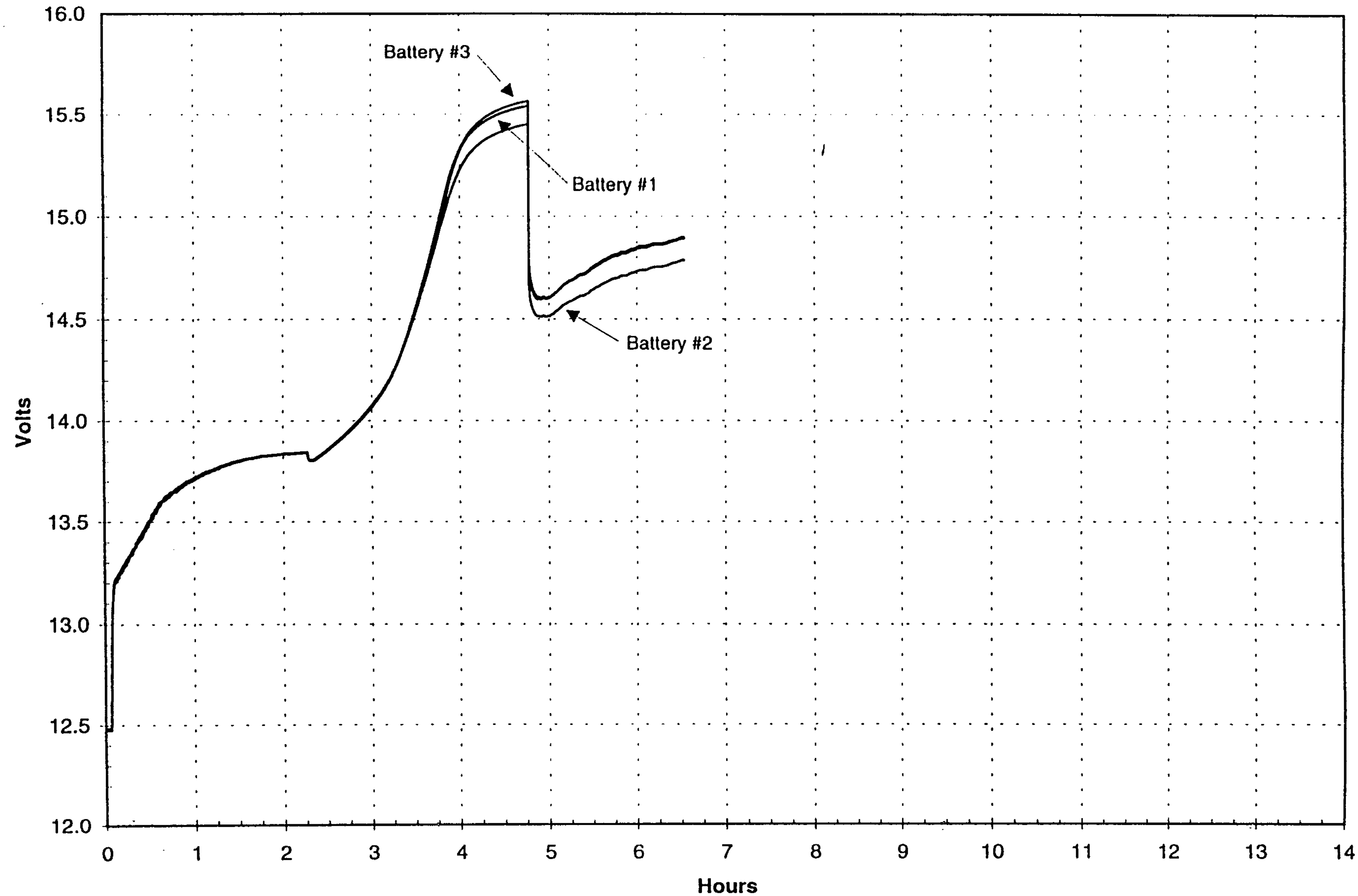
Zivan Charge Profile on City-el 4126



Comparison of Block Temperatures for Zivan Charger on City-el 4126



Comparison of Block Voltages for Zivan Charger on City-el 4126



temperature changes. The DAS records and the charge recorded with the Hydra show the voltage increasing through the constant voltage phase 2 at the same time as the temperature is increasing.

In some of the DAS files I noticed the float voltage increasing as the temperature decreased, which is expected of a temperature compensated charger. The above equation for voltage was superimposed on the recorded voltage and plotted for charge records of 9/14/95, 10/4/95, 3/16/96, and 4/30/96. These plots show that although the voltage increasing while the temperature decreased, the charger was not following the above relation. The voltage was increasing because the float current was set a little to high, and the batteries were cooling. There is no evidence the charger pays attention to the battery temperature during the constant voltage phase or the float phase. The charger may be taking the temperature into account at the point it switches from the bulk charge, high rate phase 1 to the "constant voltage" phase 2. A better data acquisition scheme would have been needed to determine if this was the case.

Specific Gravity readings taken May 29, 1995 showed the batteries were coming up to 1.26 specific gravity after a complete charge and a two hour rest. This is definitely undercharging and is consistent with the observations of the Zivan charger recorded with the Mirabor Charger test report.

We would also liked to have measured power factor, however suitable equipment was not available.

Test records mentioned in this report are attached.

Adjusting a Zivan Charger.
We recently received the K2 110 VAC, 20 Amp/72V charger for use in the Peregrin NEV Prototype. We were furnished with the following instructions for adjusting a Zivan charger.

1. Adjust the first trim pot for phase 1 current. The current may have to be reduced from 20 Amps if the charger trips a 20A breaker.

2. Unplug the charger from the battery pack, while leaving AC power on. The charger goes to the constant voltage setting and stays there for 10 seconds. The constant voltage setting can be adjusted with during this time.

If needed, the charger can be unplugged from the AC service and this step repeated until it is correct.

3. Reconnect the charger to the batteries and adjust the finish current.

We will try this method and record additional information about a Zivan Charger during development of the Peregrin.

Summary:
The Zivan charger has given good service and has provided a relatively consistent charge. The batteries used since August 95 are still providing acceptable performance, and are not exhibiting thermal runaway. The charger does not exhibit the finish charge finesse of other chargers, however price and weight considered it is a good value.

I wish the *duration* of phase 3, constant current was adjustable, since this might provide a little more overcharge and a more reliable charge completion to a higher state of charge, perhaps to a 1.29 stabilized Specific Gravity. The method of using the float phase for equalizing employed to date is only acceptable with attention by the vehicle operator.

Charger Comparison Test, Data Sheet

Vehicle: 4152 Charger: Zivan

Trip

Date: ______

DAS Filename: ______

Start Time: ______ DC Energy Start: ______ Amp-hr/W-hr

Hill Climb Time: ______

End Time: ______ DC Energy End: ______ Amp-hr/W-hr

Charge

Date: ______

DAS Filename: ______

Start Time: ______ DC Energy Start: ______ Amp-hr/W-hr

End Time: ______ DC Energy End: ______ Amp-hr/W-hr

Disconnect Time: ______

State of Charge Measurements

Date: 5-29-96 Time: 8:54 AM

	Batt 1	Batt 2	Batt 3
Temp: (deg. C)			
Voltage:	12.52	12.52	12.55
SG cell 1:	1.255	1.255	1.260
SG cell 2:	1.255	1.260	1.260
SG cell 3:	1.255	1.270	1.260
SG cell 4:	1.260	1.260	1.265
SG cell 5:	1.270	1.260	1.265
SG cell 6:	1.250	1.260	1.270

Note: Battery 1 is the left most battery as viewed from the rear. Battery 3 is the right most battery. Cell 1 is closest to the positive terminal, and Cell 6 is closest to the negative terminal.

City-el DAS Charge Data

VIN#: 4152
Date: 6-28-95
Time: 6:51 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	43.64	22.79	36.49	0.99
2	0	47.18	22.46	43.47	2.05
3	0	46.33	22.59	52.66	3.10
4	0	43.09	13.95	59.25	3.70
5	0	38.51	0.06	57.86	3.70
6	0	38.41	0.06	53.78	3.71
7	0	38.35	0.05	49.93	3.71
8	0	38.3	0.05	46.5	3.71
9	0	38.24	0.05	43.39	3.71
10	0	38.24	0.04	40.63	3.71
11	0	38.18	0.04	38.16	3.72
12	0	38.14	0.04	35.61	3.72

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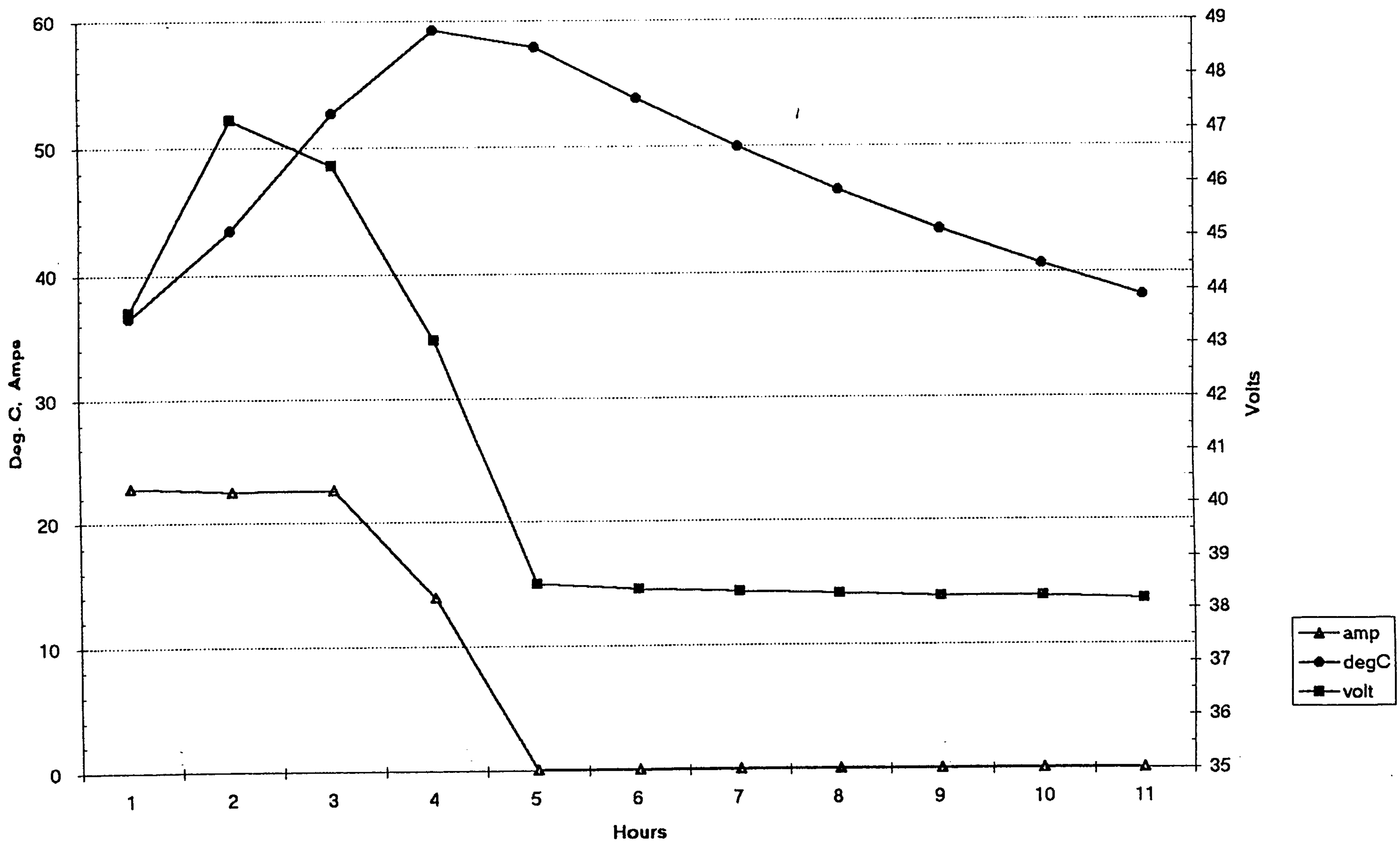
Date: 6-28-95 6:51 PM

VIN: 4152

City-el Charge Profile



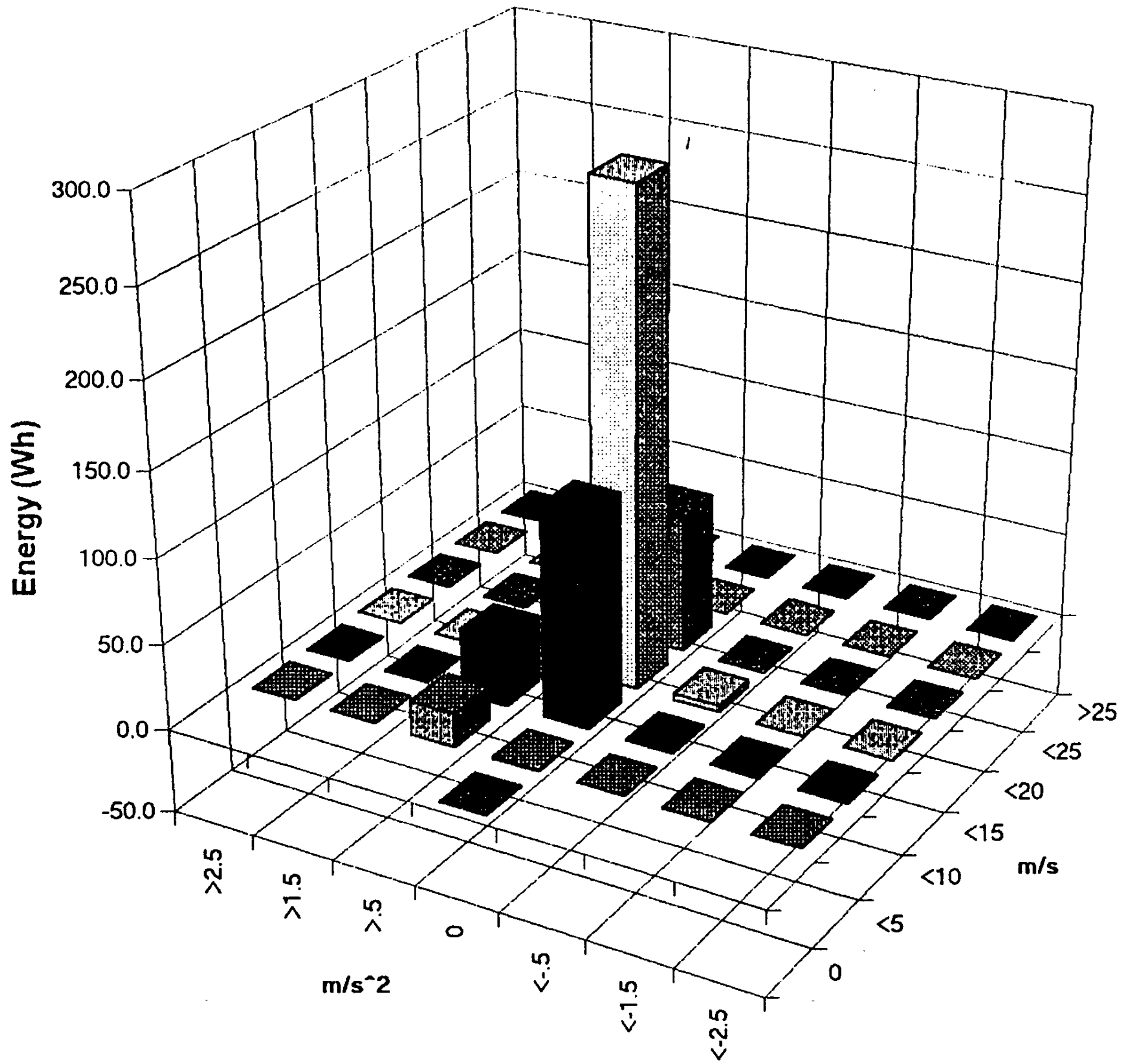
City-el Trip Performance

Date: 6-28-95 5:58 PM

VIN: 4152

Trip Data:

35.6	Deg. C
10728	Meters
560	Watt-hours
84	Wh/mile



City-el Trip Performance

Date: 6-29-95 7:26 AM

VIN: 4152

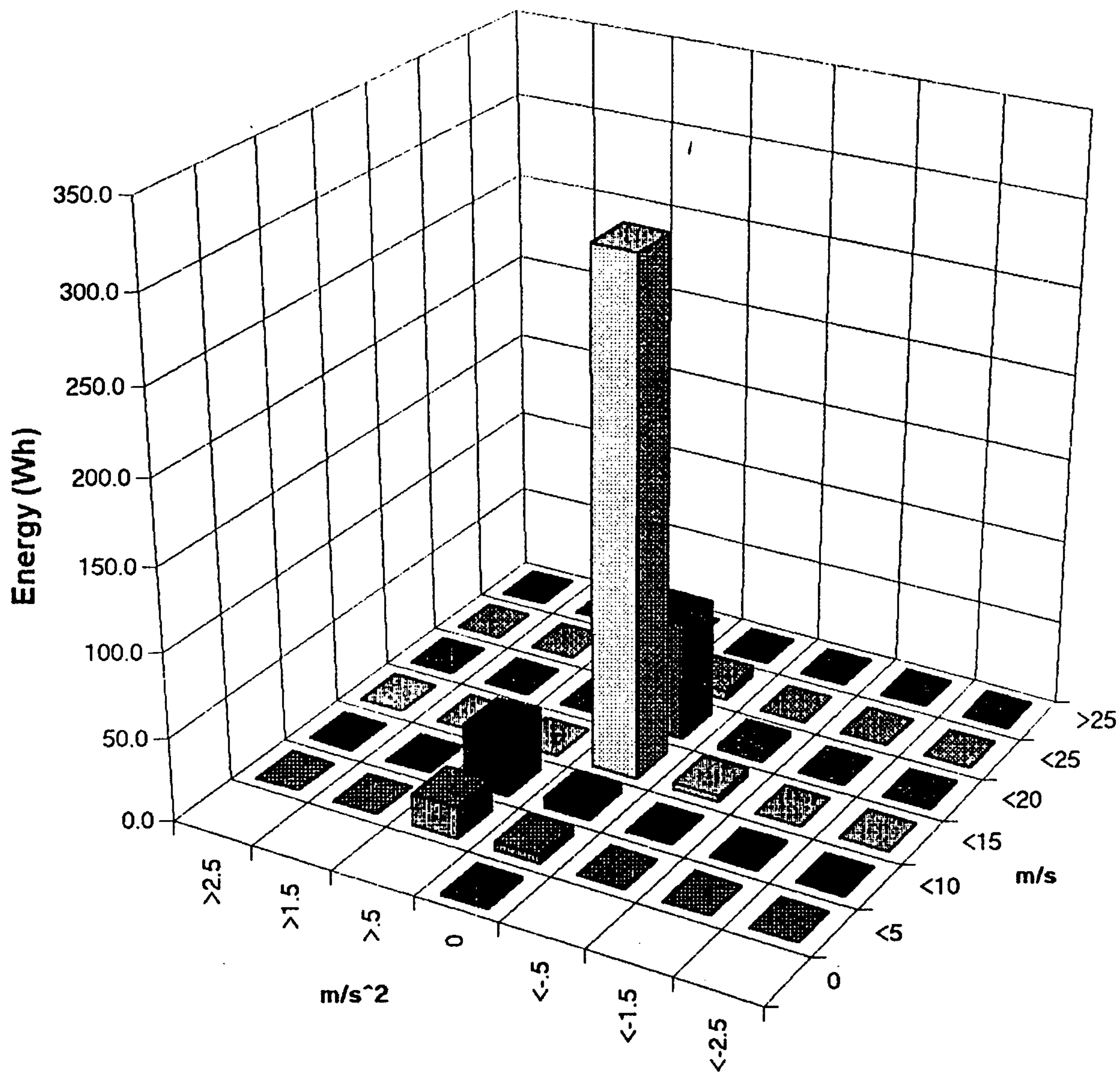
Trip Data:

30.7 Deg. C

10707 Meters

453 Watt-hours

68 Wh/mile



City-el DAS Charge Data

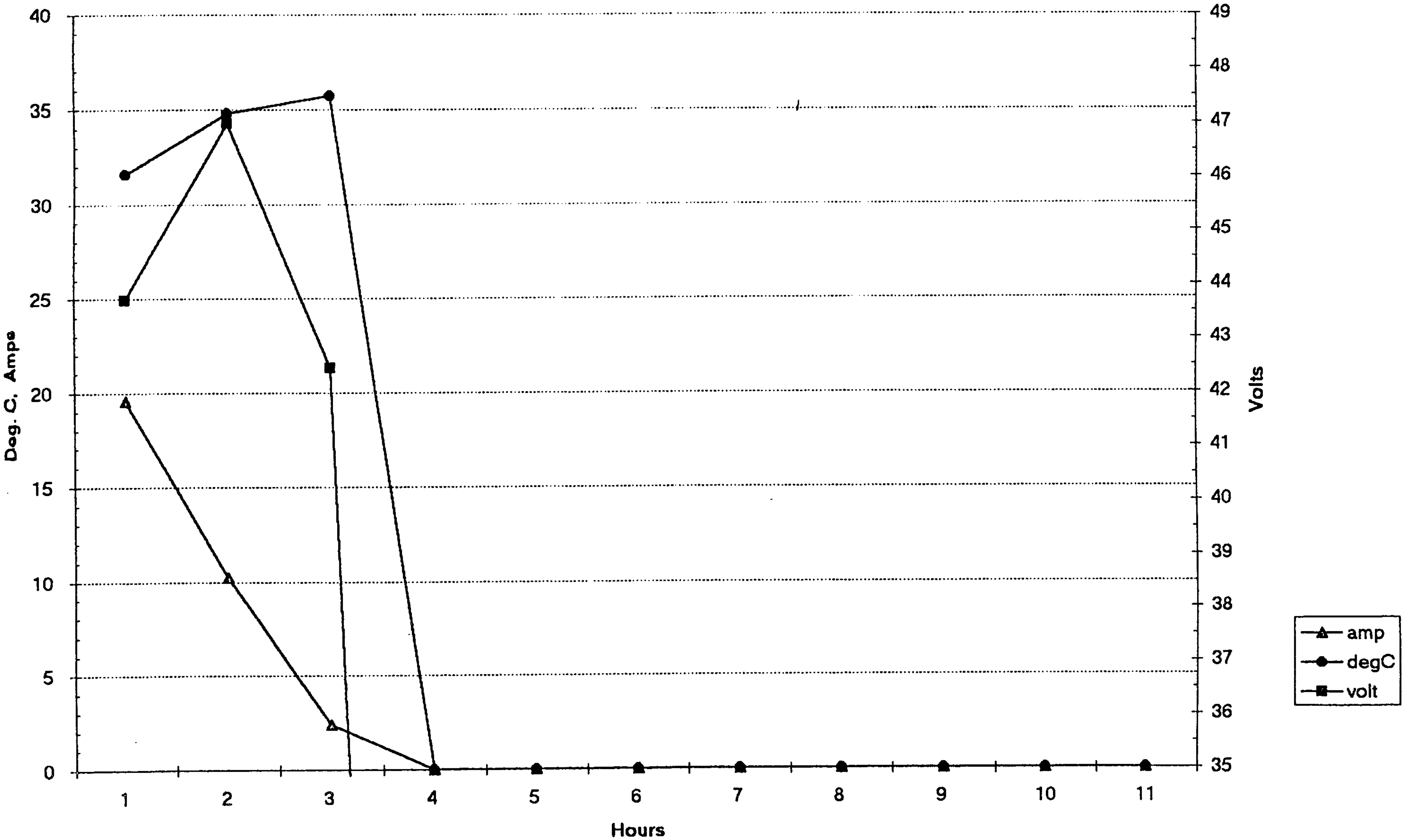
VIN#: 4152
Date: 6-29-95
Time: 8:10 AM

hour	AC W	volt	amp	degC	DC kWh
1	0	43.73	19.57	31.59	0.86
2	0	47	10.23	34.77	1.34
3	0	42.46	2.39	35.72	1.44
4	0	0	0	0	1.44
5	0	0	0	0	1.44
6	0	0	0	0	1.44
7	0	0	0	0	1.44
8	0	0	0	0	1.44
9	0	0	0	0	1.44
10	0	0	0	0	1.44
11	0	0	0	0	1.44
12	0	0	0	0	1.44

Date: 6-29-95 8:10 AM

VIN: 4152

City-el Charge Profile



City-el DAS Charge Data

VIN#: 4152
Date: 7-12-95
Time: 2:52 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	39.52	21.89	37.55	0.87
2	0	43.45	22.98	28.86	1.86
3	0	41.87	9.63	30.56	2.27
4	0	41.38	5.5	30.29	2.49
5	0	41.9	4.32	30.43	2.68
6	0	39.9	-0.01	30.3	2.67
7	0	0	0	0	2.67
8	0	0	0	0	2.67
9	0	0	0	0	2.67
10	0	0	0	0	2.67
11	0	0	0	0	2.67
12	0	0	0	0	2.67

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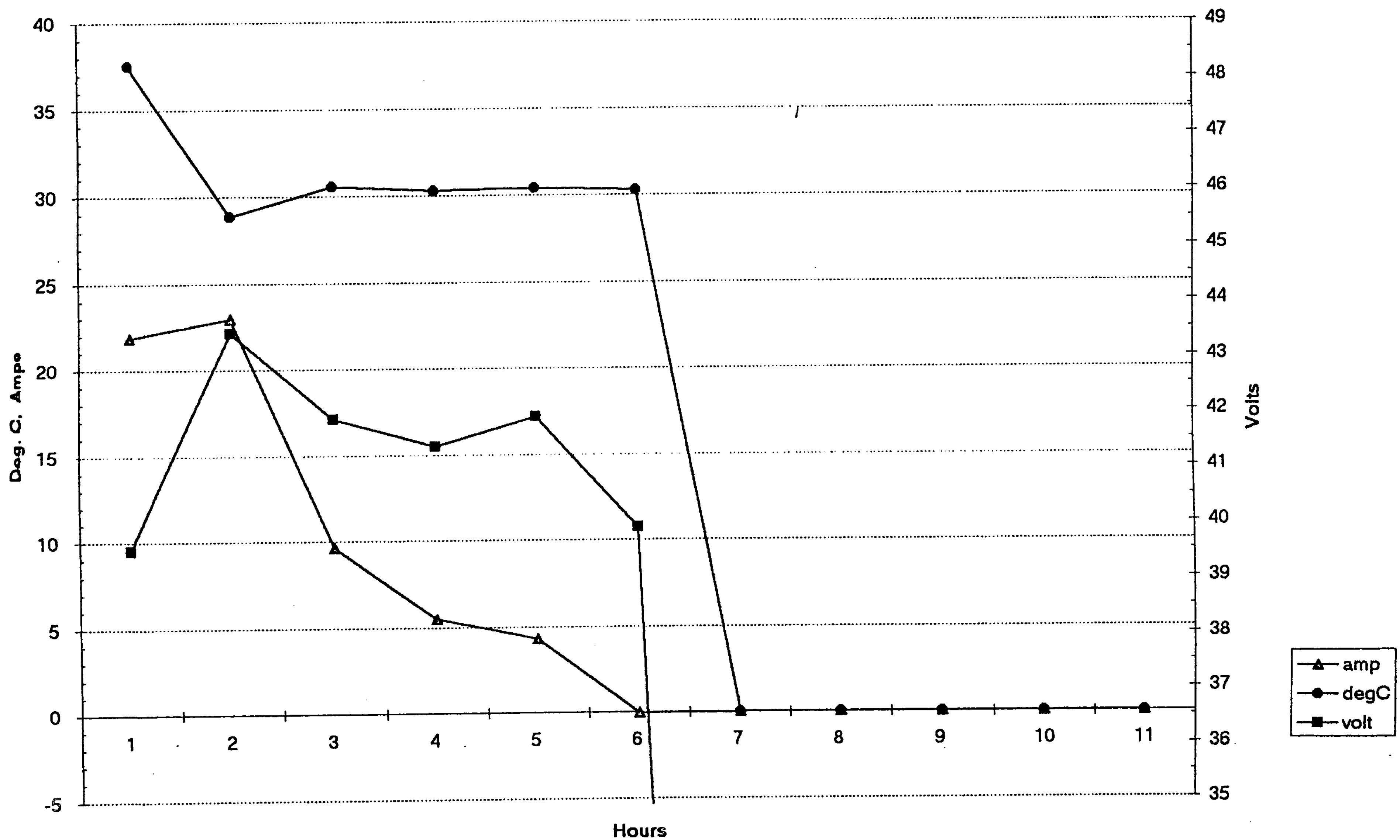
Date: 7-12-95 2:52 PM

VIN: 4152

City-el Charge Profile



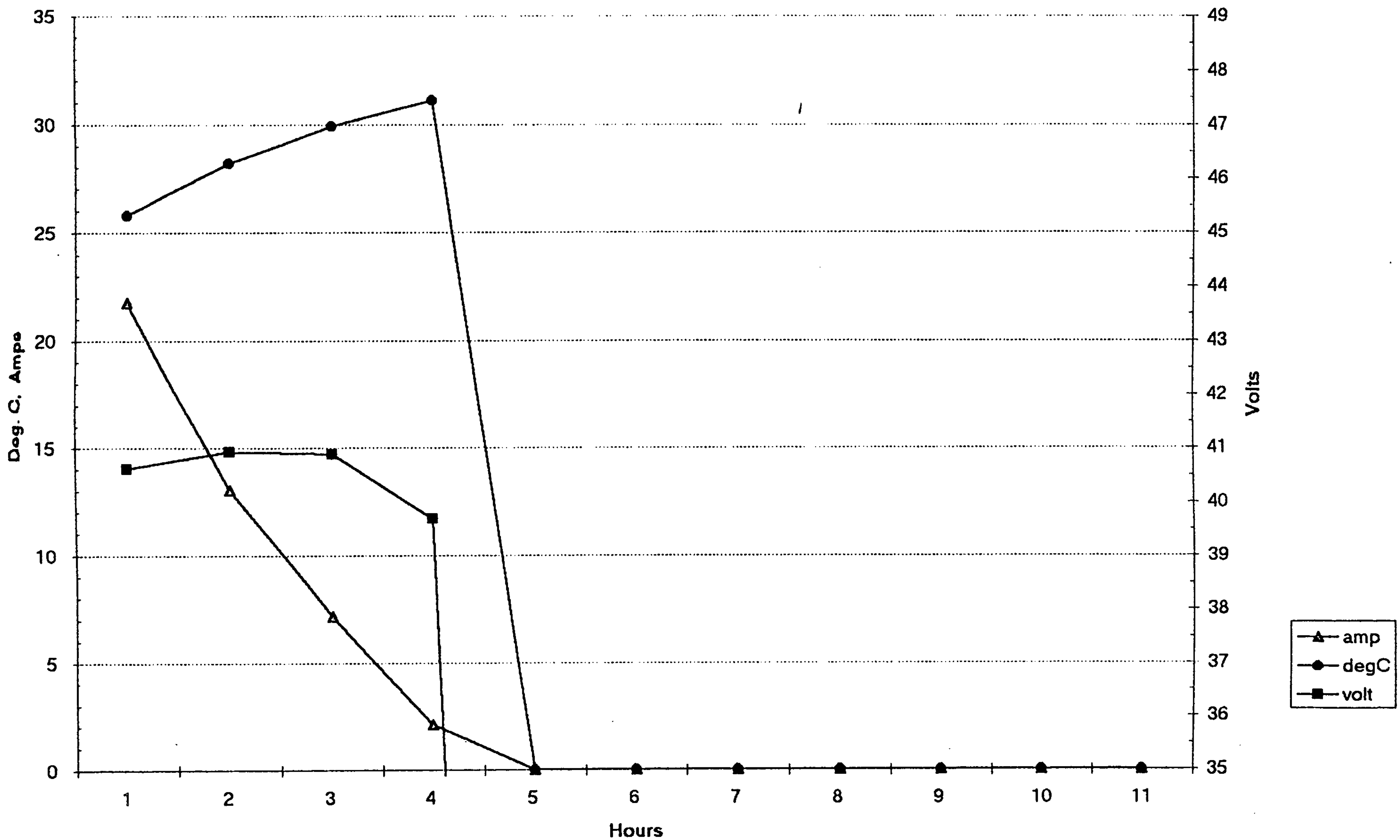
City-el DAS Charge Data

VIN#: 4152
Date: 8-1-95
Time: 12:53 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	40.62	21.76	25.79	0.88
2	0	40.92	13.03	28.19	1.42
3	0	40.88	7.2	29.9	1.71
4	0	39.69	2.11	31.08	1.80
5	0	0	0	0	1.80
6	0	0	0	0	1.80
7	0	0	0	0	1.80
8	0	0	0	0	1.80
9	0	0	0	0	1.80
10	0	0	0	0	1.80
11	0	0	0	0	1.80
12	0	0	0	0	1.80

Date: 8-1-95 12:53 PM
VIN: 4152

City-el Charge Profile



City-el DAS Charge Data

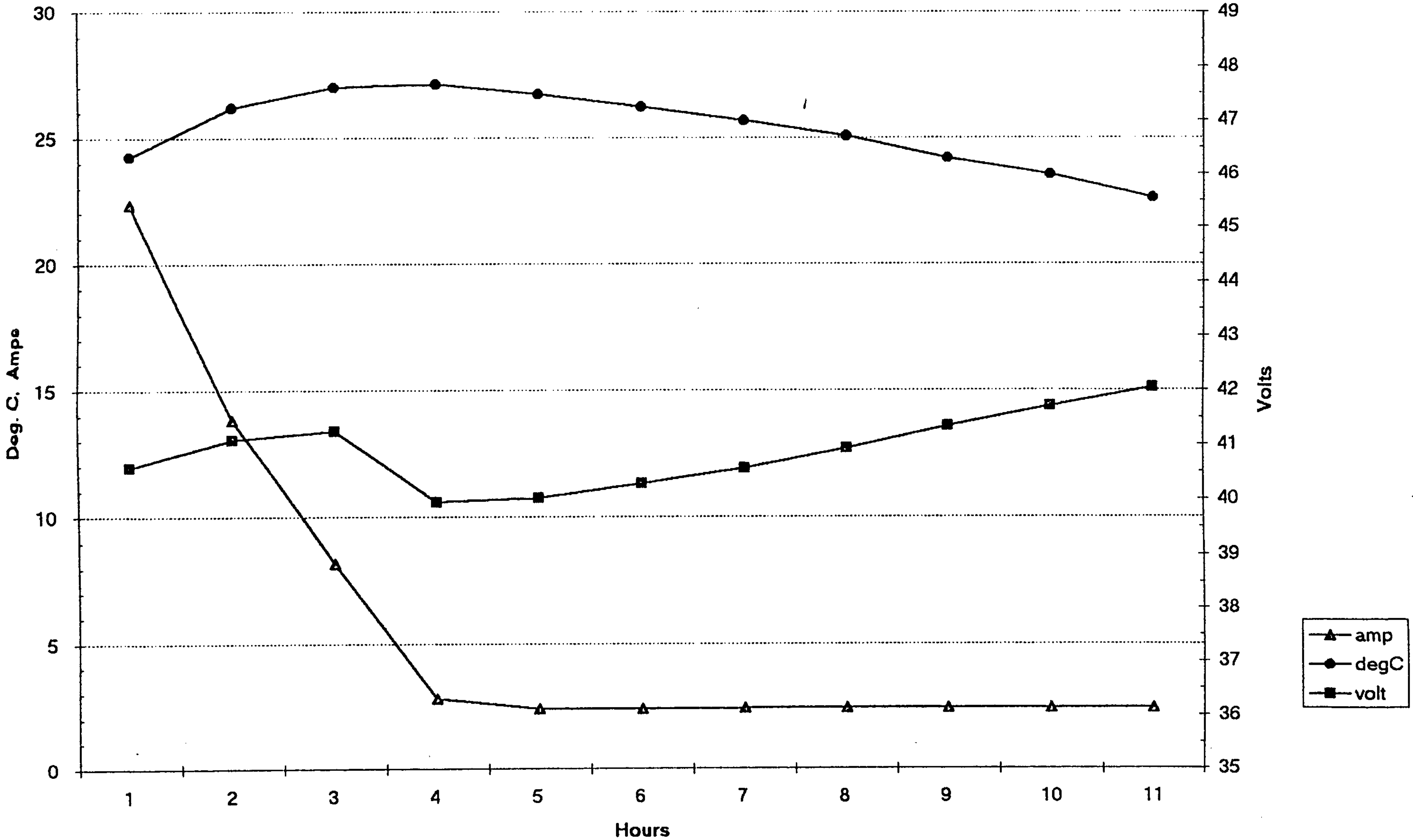
VIN#: 4152
Date: 8-10-95
Time: 5:32 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	40.57	22.33	24.24	0.91
2	0	41.09	13.83	26.18	1.47
3	0	41.25	8.22	27.01	1.81
4	0	39.94	2.8	27.13	1.93
5	0	40.01	2.4	26.72	2.02
6	0	40.27	2.41	26.21	2.12
7	0	40.56	2.42	25.67	2.22
8	0	40.93	2.42	25.07	2.32
9	0	41.34	2.42	24.19	2.42
10	0	41.71	2.42	23.53	2.52
11	0	42.05	2.42	22.58	2.62
12	0	42.55	2.41	21.65	2.72

Date: 8-10-95 5:32 PM

VIN: 4152

City-el Charge Profile



City-el DAS Charge Data

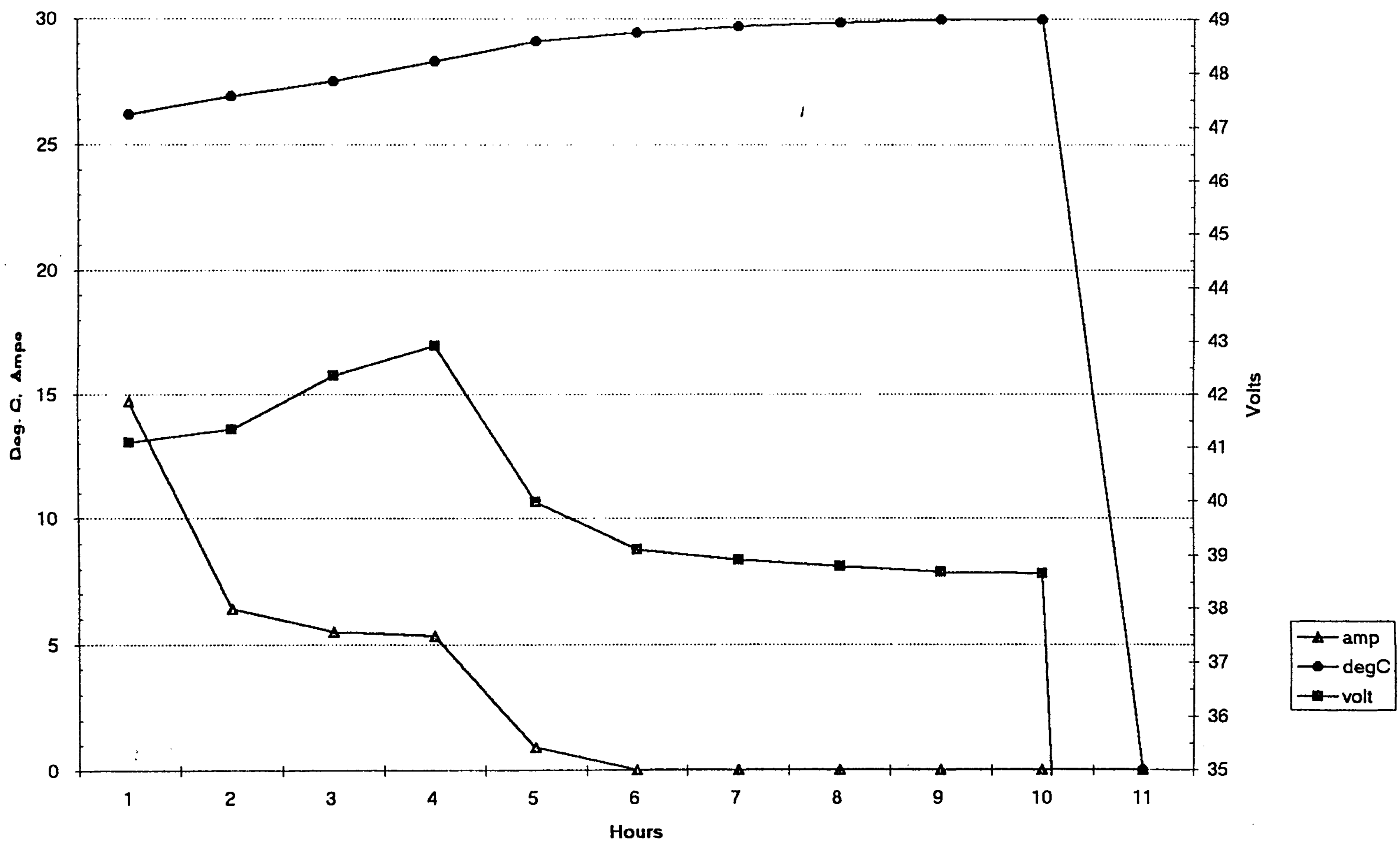
VIN#: 4152
Date: 8-15-95
Time: 8:53 AM

hour	AC W	volt	amp	degC	DC kWh
1	0	41.08	14.71	26.18	0.60
2	0	41.33	6.42	26.89	0.87
3	0	42.36	5.48	27.49	1.10
4	0	42.92	5.34	28.29	1.33
5	0	39.96	0.93	29.07	1.37
6	0	39.09	0	29.42	1.37
7	0	38.9	0	29.67	1.37
8	0	38.78	0	29.84	1.37
9	0	38.68	0	29.97	1.37
10	0	38.65	0	29.98	1.37
11	0	0	0	0	1.37
12	0	0	0	0	1.37

Print Da[illegible]-11-95

Date: 8-15-95 8:53 AM
VIN: 4152

City-el Charge Profile



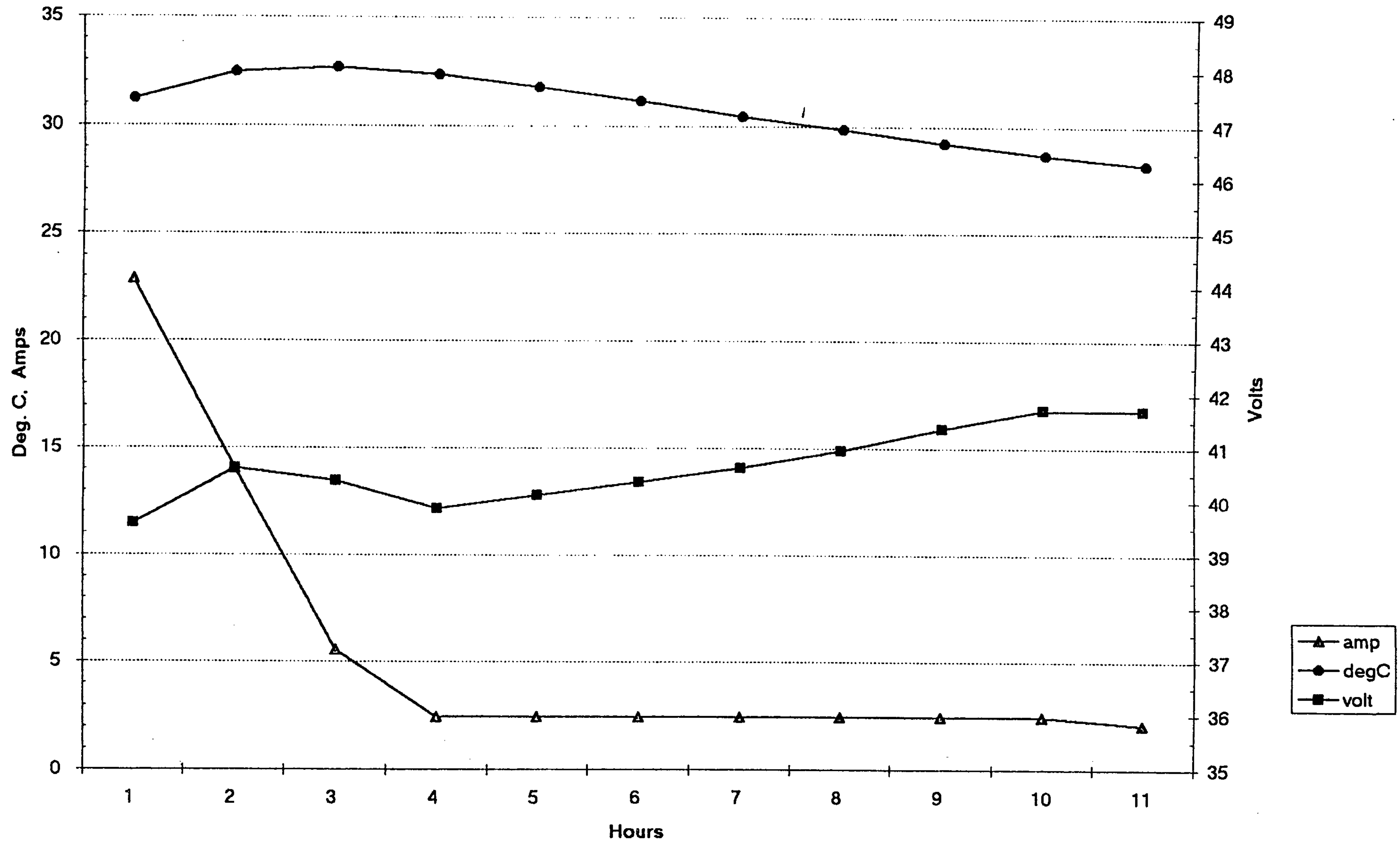
City-el DAS Charge Data

VIN#: 4152
Date: 8-22-95
Time: 8:35 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	39.59	22.88	31.19	0.91
2	0	40.61	14.04	32.45	1.48
3	0	40.38	5.56	32.67	1.70
4	0	39.87	2.42	32.34	1.80
5	0	40.11	2.42	31.75	1.89
6	0	40.36	2.44	31.12	1.99
7	0	40.63	2.44	30.44	2.09
8	0	40.96	2.44	29.85	2.19
9	0	41.36	2.45	29.22	2.29
10	0	41.72	2.44	28.66	2.39
11	0	41.71	2.05	28.17	2.48
12	0	38.93	0	26.72	2.48

Date: 8-22-95 8:35 PM
VIN: 4152

City-el Charge Profile



City-el DAS Charge Data

VIN#: 4152
Date: 8-23-95
Time: 6:40 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	40.32	17.28	31.7	0.70
2	0	41.88	5.73	31.87	0.94
3	0	43.44	5.47	31.74	1.17
4	0	43.14	4.35	31.88	1.36
5	0	41.99	2.43	31.41	1.46
6	0	42.49	2.44	30.63	1.57
7	0	42.85	2.44	29.86	1.67
8	0	43.12	2.45	29.18	1.78
9	0	43.38	2.45	28.54	1.88
10	0	43.61	2.45	27.94	1.99
11	0	43.85	2.45	27.4	2.10
12	0	44.09	2.43	26.8	2.21

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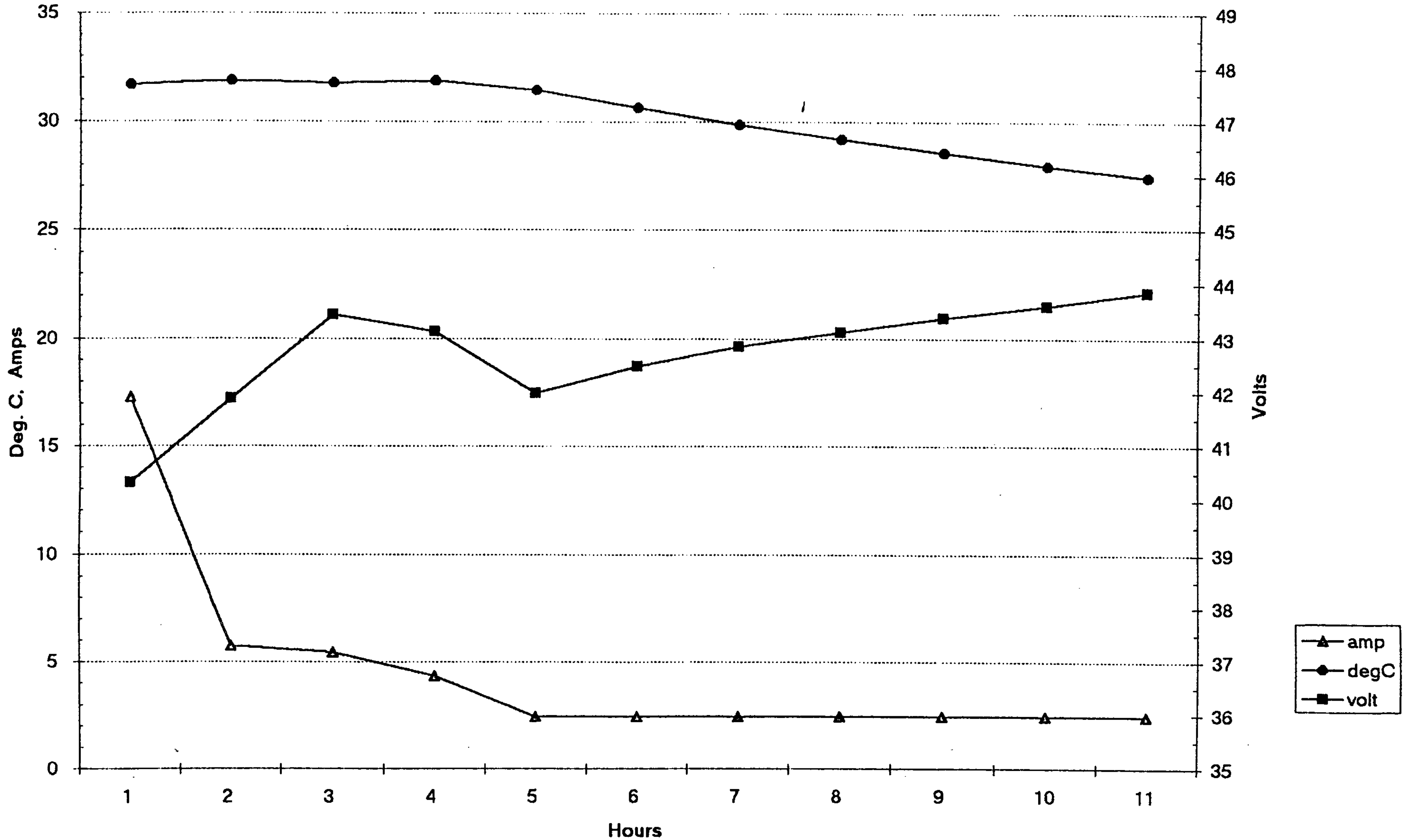
Date: 8-23-95 6:40 PM
VIN: 4152

City-el Charge Profile



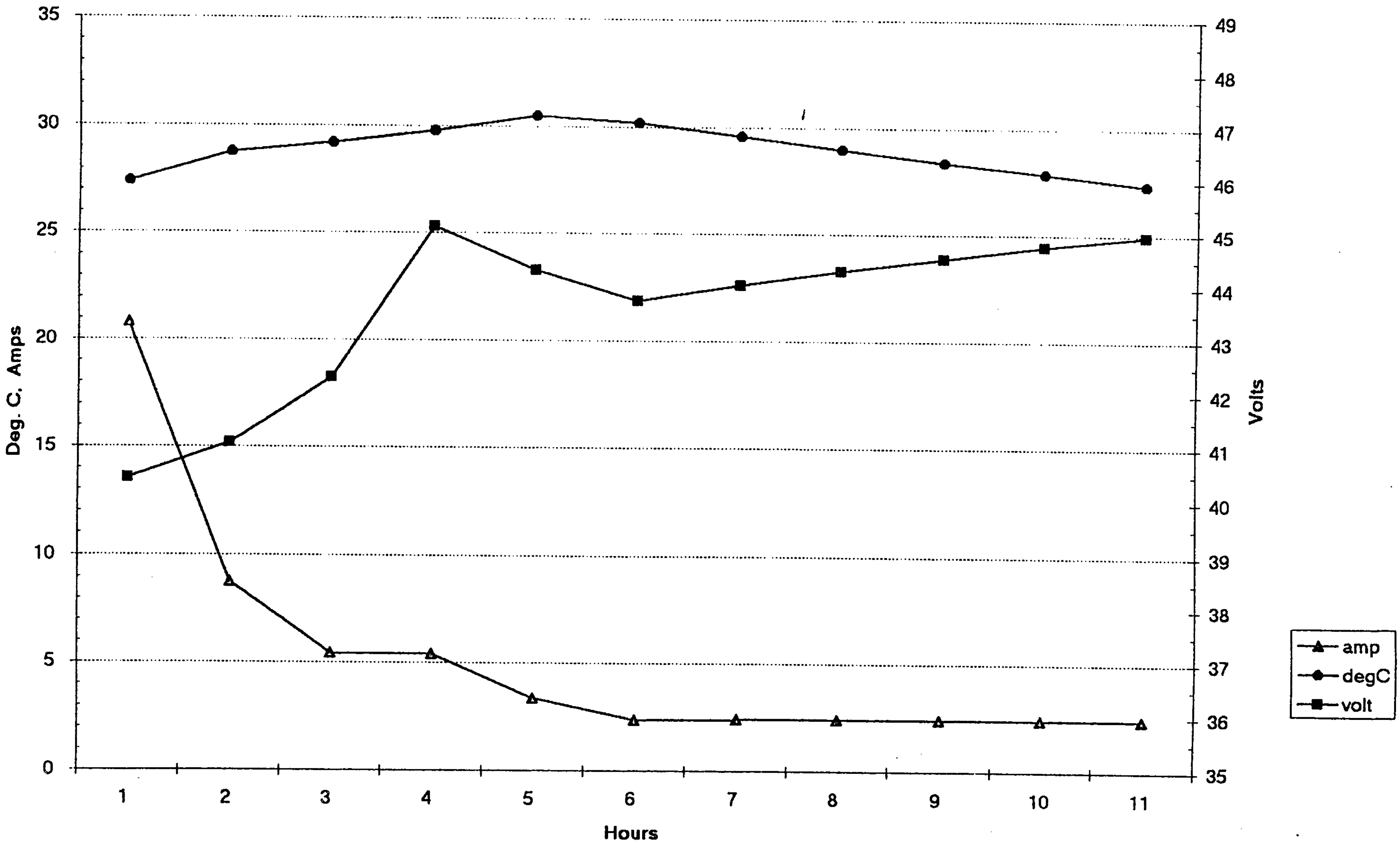
City-el DAS Charge Data

VIN#: 4152
Date: 8-24-95
Time: 5:52 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	40.41	20.81	27.42	0.84
2	0	41.07	8.78	28.76	1.20
3	0	42.29	5.45	29.21	1.43
4	0	45.13	5.42	29.77	1.68
5	0	44.32	3.37	30.46	1.83
6	0	43.76	2.37	30.19	1.93
7	0	44.05	2.38	29.59	2.03
8	0	44.31	2.39	28.99	2.14
9	0	44.55	2.39	28.41	2.25
10	0	44.78	2.4	27.88	2.35
11	0	44.97	2.4	27.33	2.46
12	0	42.02	1.22	25.38	2.51

Date: 8-24-95 5:52 PM
VIN: 4152

City-el Charge Profile



City-el DAS Charge Data

VIN#: 4152
Date: 9-2-95
Time: 7:59 PM

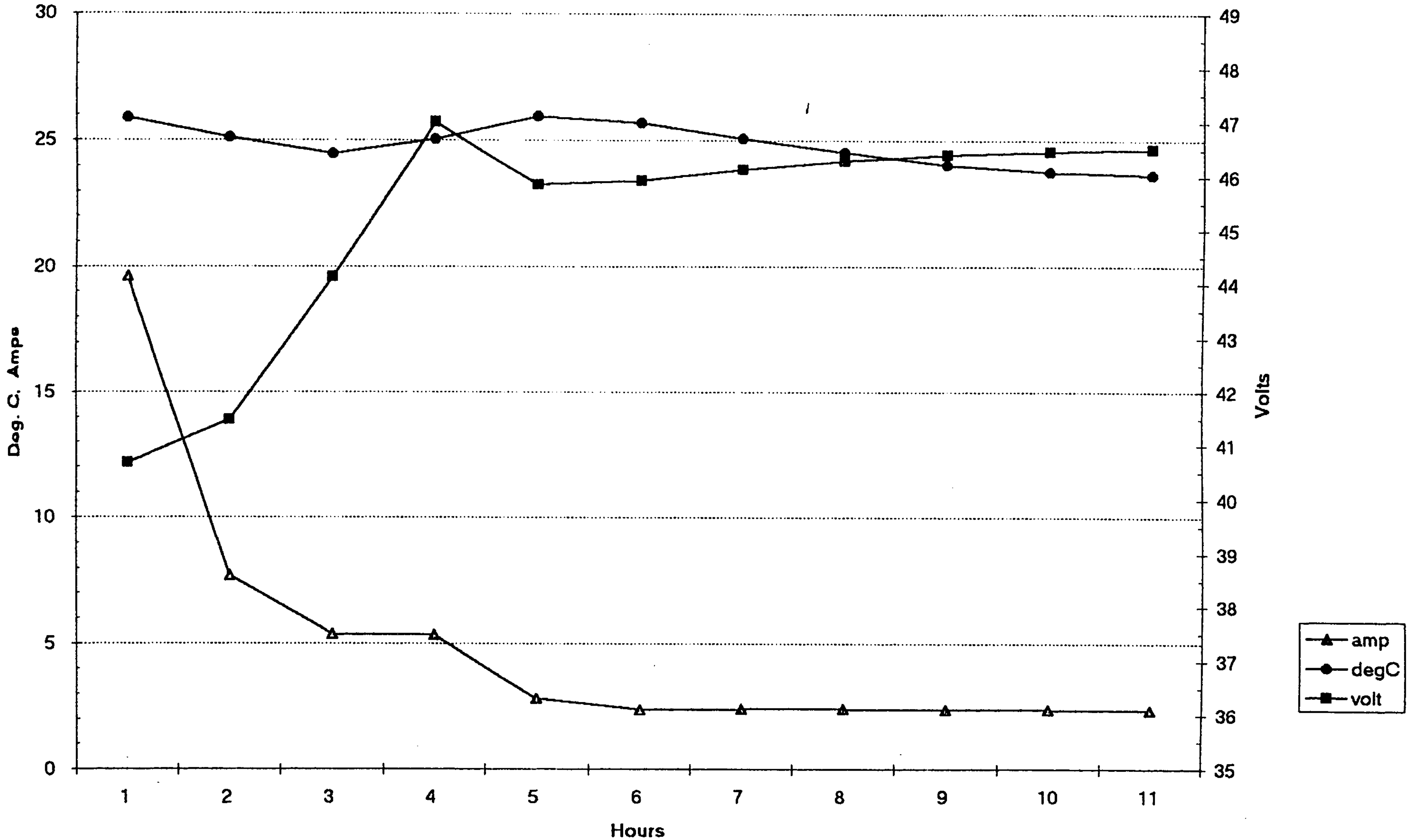
hour	AC W	volt	amp	degC	DC kWh
1	0	40.67	19.62	25.85	0.80
2	0	41.49	7.72	25.11	1.12
3	0	44.13	5.37	24.46	1.36
4	0	46.99	5.34	25.04	1.61
5	0	45.85	2.8	25.93	1.73
6	0	45.92	2.38	25.67	1.84
7	0	46.13	2.39	25.06	1.95
8	0	46.29	2.39	24.54	2.06
9	0	46.4	2.38	24.03	2.18
10	0	46.46	2.36	23.76	2.28
11	0	46.51	2.35	23.62	2.39
12	0	45.95	2.06	23.58	2.49

Print [illegible] 10-11-95

Date: 9-2-95 7:59 PM

VIN: 4152

City-el Charge Profile



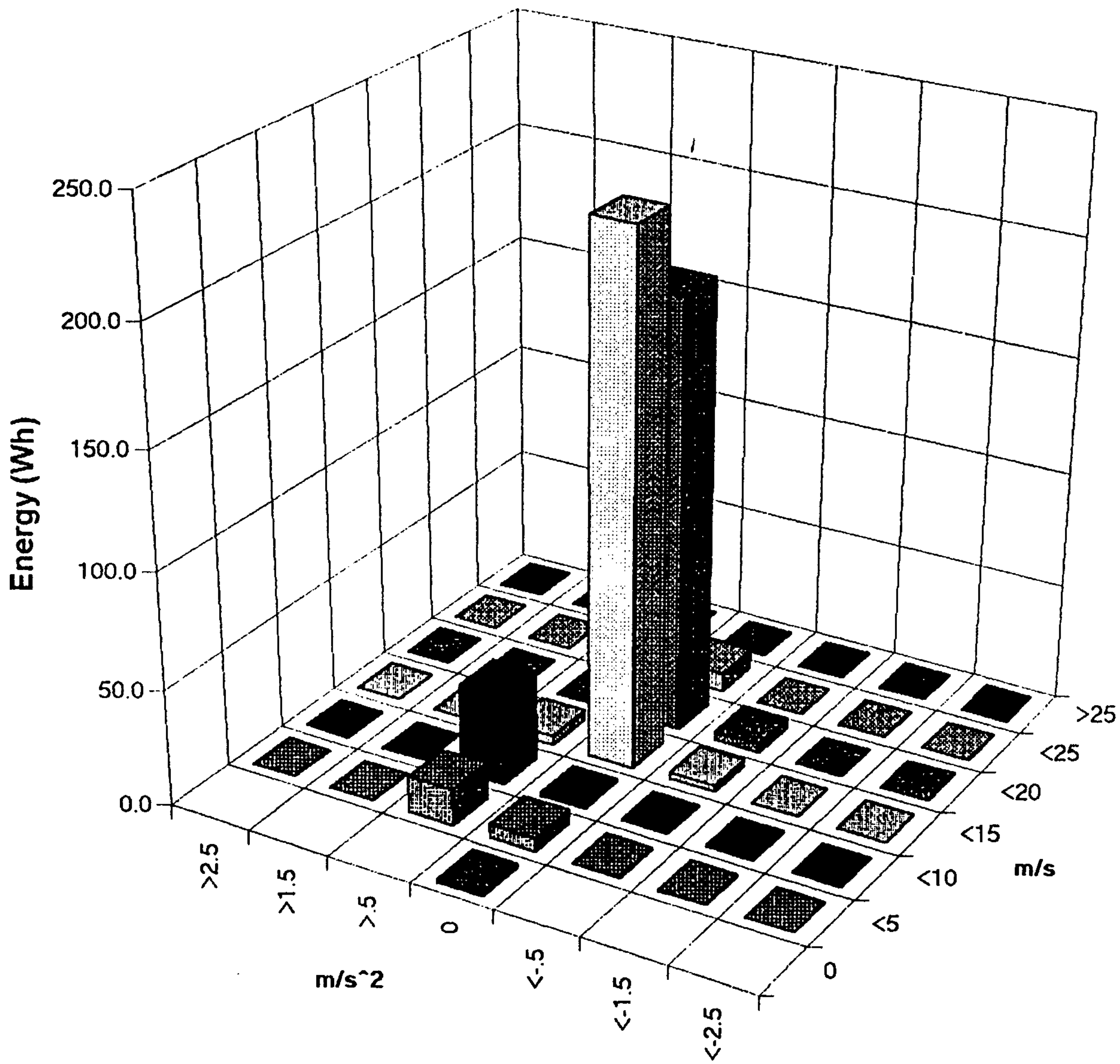
City-el Trip Performance

Date: 9-3-95 8:36 AM

VIN: 4152

Trip Data:

23.4	Deg. C
10672	Meters
493	Watt-hours
74	Wh/mile



City-el Trip Performance

Date: 9-3-95 4:16 PM

VIN: 4152

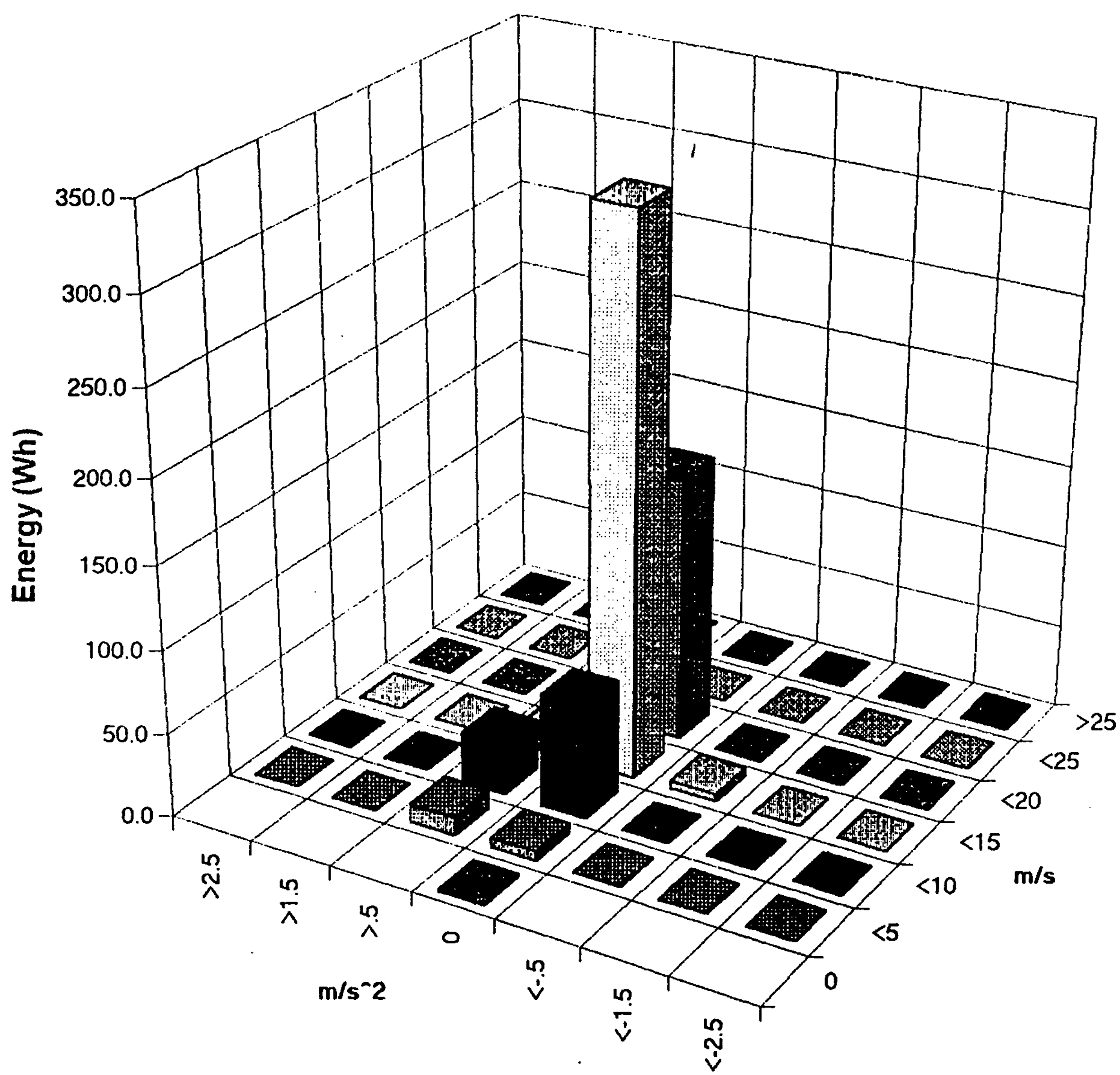
Trip Data:

26.7 Deg. C

10786 Meters

616 Watt-hours

92 Wh/mile



City-el DAS Charge Data

VIN#: 4152
Date: 9-3-95
Time: 4:57 PM

hour	AC W	volt	amp	degC	DC kWh
1	0	40.8	18.6	26.73	0.76
2	0	41.44	7.03	26.43	1.05
3	0	45.01	5.4	26.21	1.29
4	0	47.23	5.38	26.98	1.55
5	0	45.76	2.44	27.42	1.66
6	0	45.91	2.38	27.19	1.77
7	0	46.09	2.4	26.79	1.88
8	0	46.23	2.43	26.25	1.99
9	0	46.39	2.44	25.57	2.10
10	0	46.5	2.45	24.85	2.22
11	0	46.63	2.45	24.11	2.33
12	0	46.79	2.43	22.77	2.45

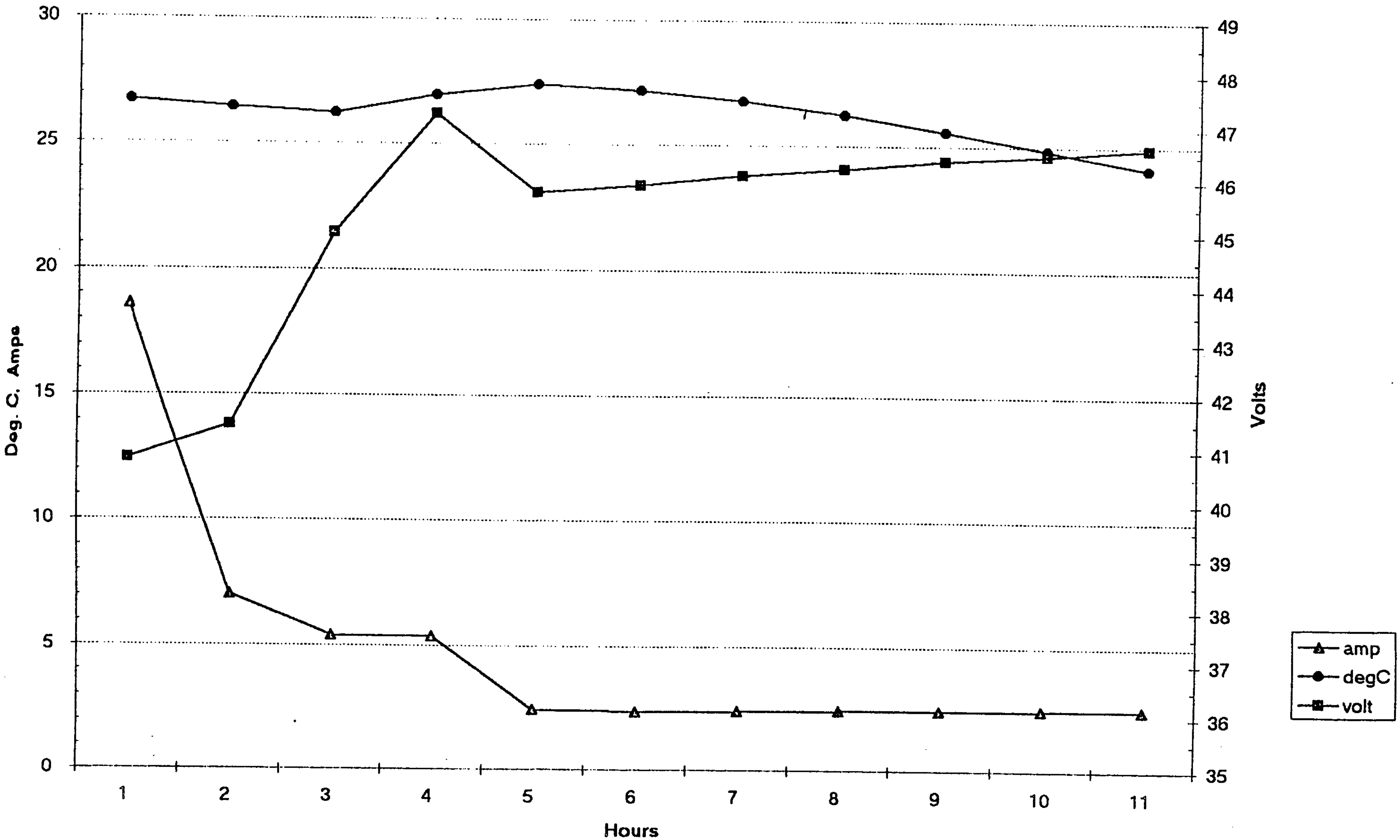
C DAS Charge Analysis

Prin e: 10-12-95

Date: 9-3-95 4:57 PM

VIN: 4152

City-el Charge Profile



Pacific EV: BOXANA1 Chart 14

Chart

City-el DAS Charge Data

VIN#: 4152
Date: 9-9-95
Time: 5:57 PM

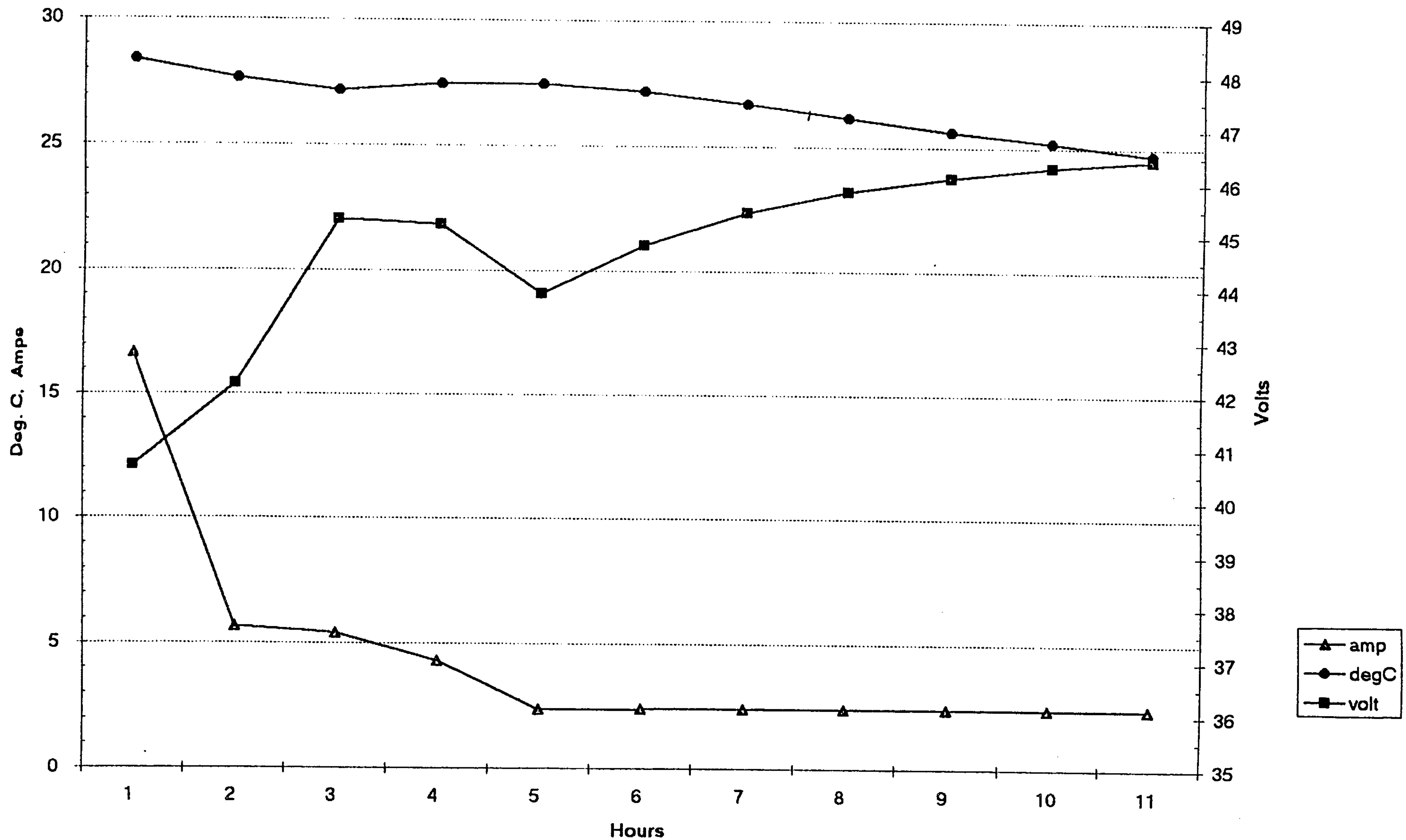
hour	AC W	volt	amp	degC	DC kWh
1	0	40.64	16.63	28.39	0.68
2	0	42.19	5.64	27.65	0.91
3	0	45.29	5.39	27.2	1.16
4	0	45.2	4.28	27.47	1.35
5	0	43.9	2.38	27.47	1.46
6	0	44.82	2.39	27.18	1.56
7	0	45.43	2.4	26.67	1.67
8	0	45.83	2.4	26.14	1.78
9	0	46.1	2.41	25.61	1.89
10	0	46.31	2.41	25.19	2.00
11	0	46.43	2.39	24.73	2.12
12	0	45.03	1.8	24.27	2.20

Print e: 10-12-95

Date: 9-9-95 5:57 PM

VIN: 4152

City-el Charge Profile



City-el DAS Charge Data

VIN#: 4152
Date: 9-10-95
Time: 3:20 PM

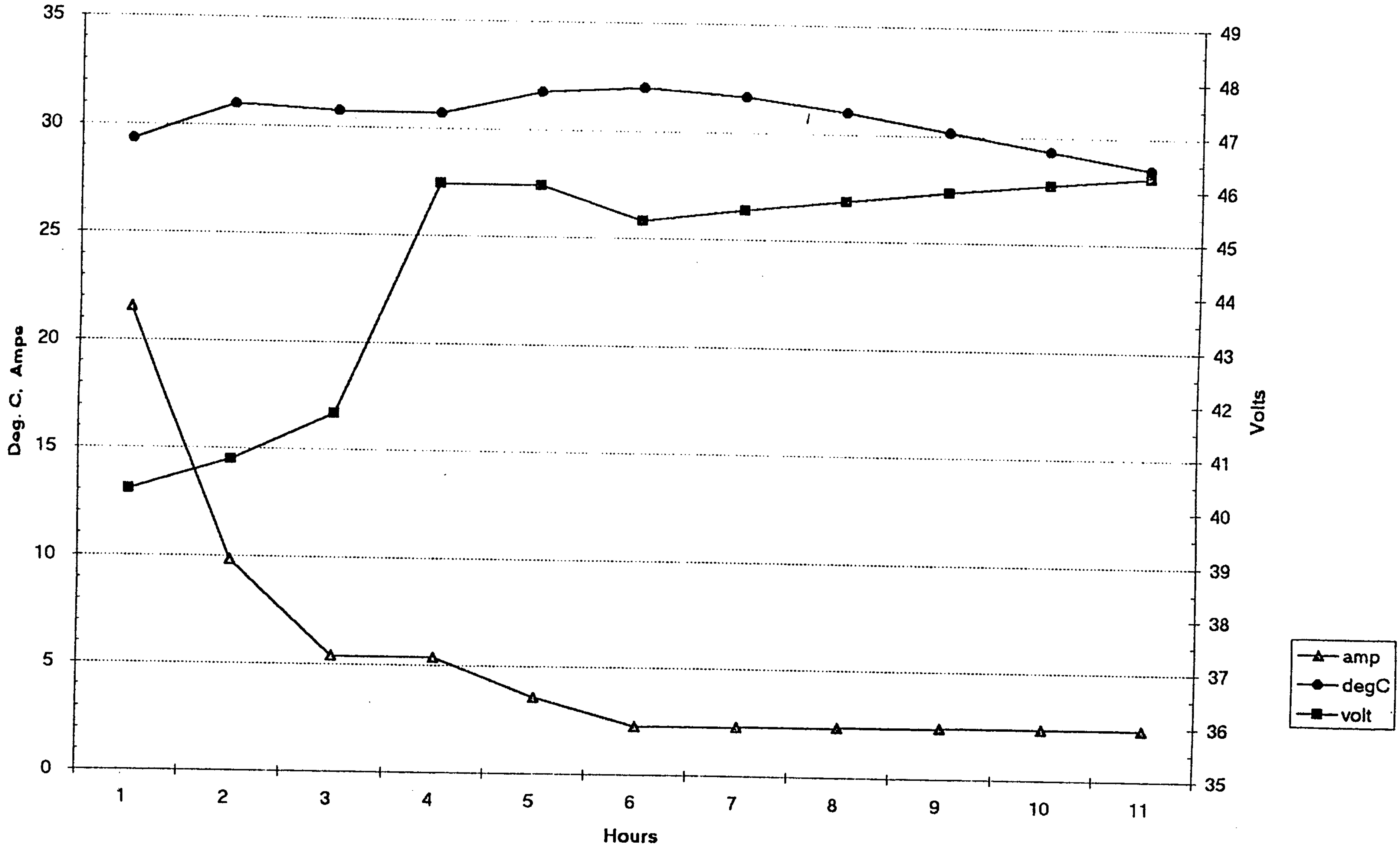
hour	AC W	volt	amp	degC	DC kWh
1	0	40.21	21.56	29.34	0.87
2	0	40.79	9.84	30.98	1.27
3	0	41.68	5.42	30.74	1.49
4	0	45.98	5.38	30.68	1.74
5	0	45.97	3.58	31.76	1.91
6	0	45.33	2.28	32.02	2.01
7	0	45.55	2.31	31.63	2.11
8	0	45.75	2.35	30.98	2.22
9	0	45.93	2.38	30.15	2.33
10	0	46.1	2.39	29.32	2.44
11	0	46.24	2.4	28.52	2.55
12	0	46.62	2.41	26.42	2.67

Print e: 10-12-95

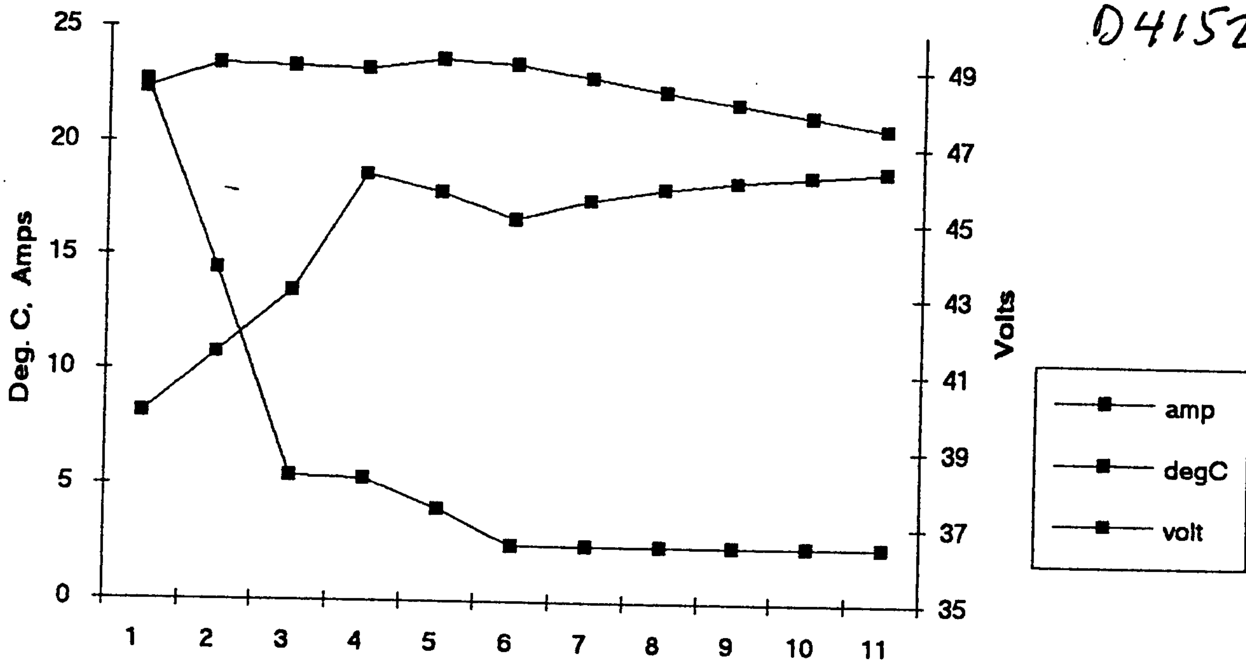
Date: 9-10-95 3:20 PM

VIN: 4152

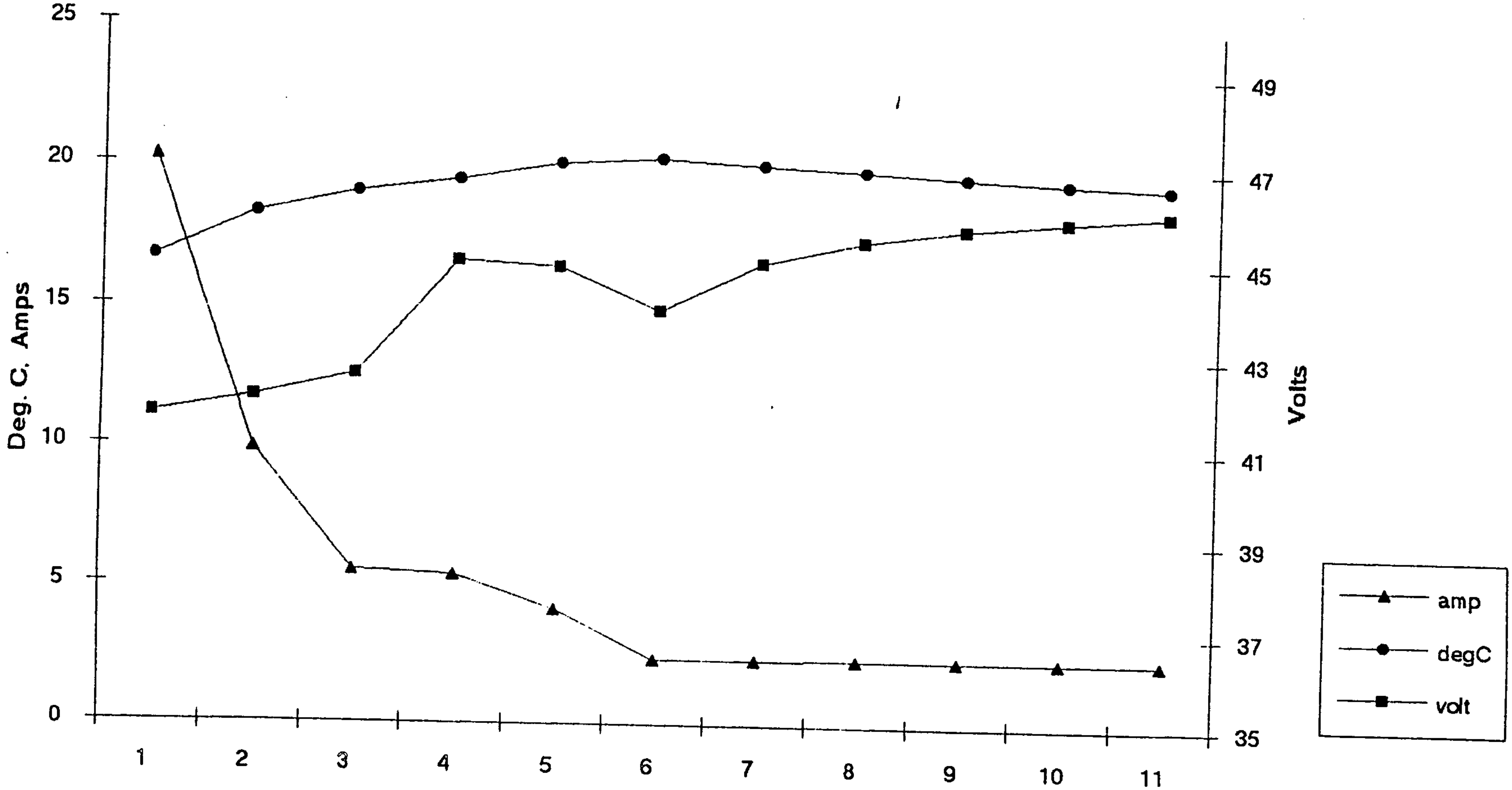
City-el Charge Profile



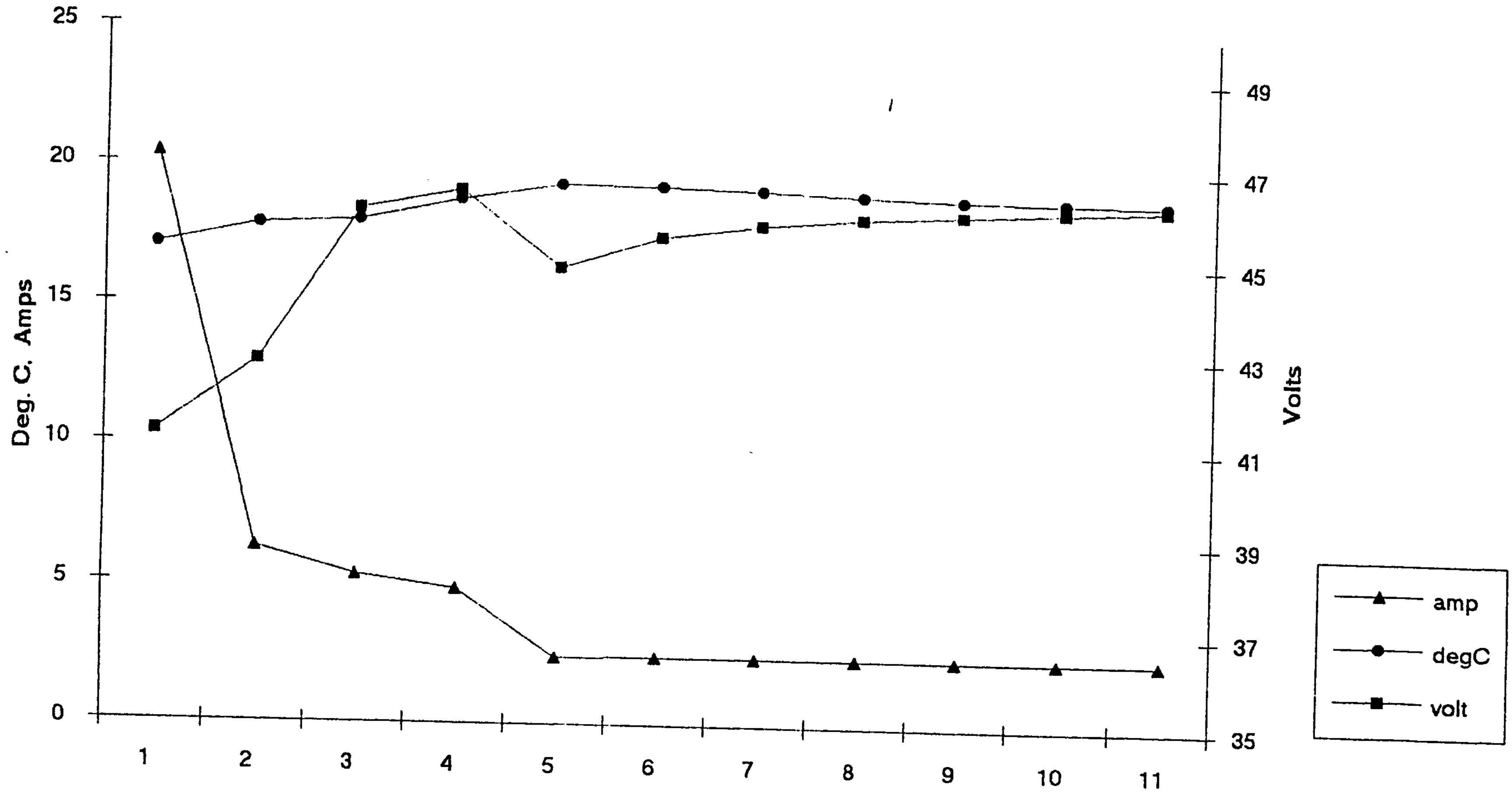
ZIVAN
D1526018.XLS
11/13/95
7:50 PM
4152
D41526018



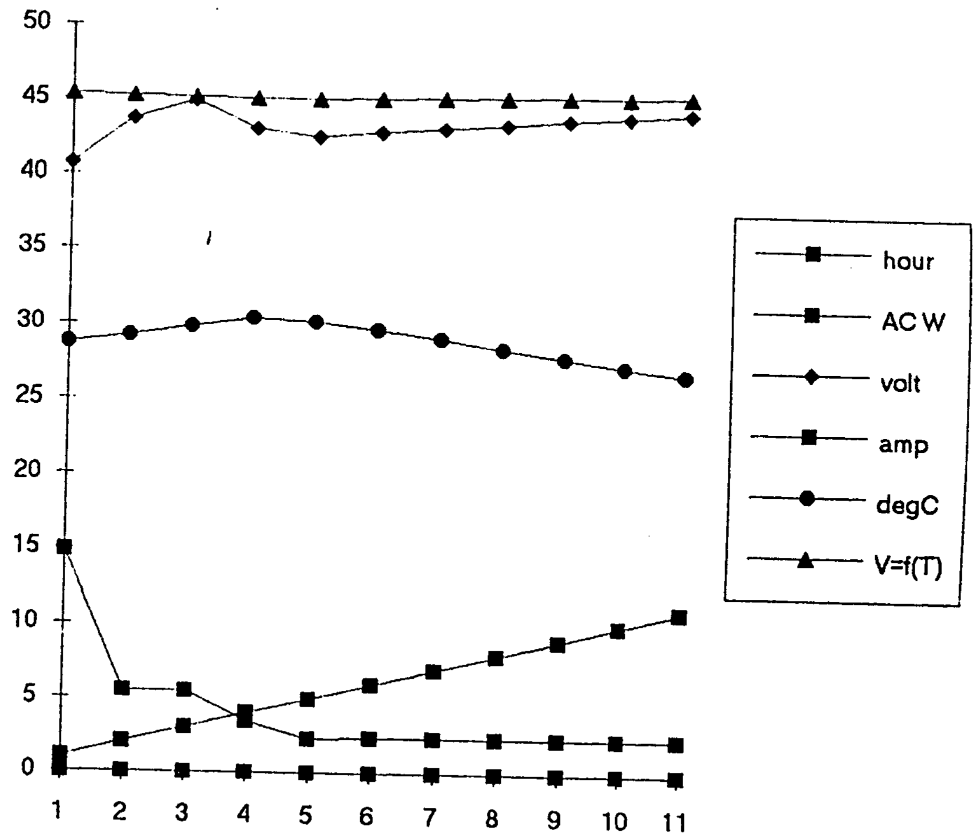
Charge on 3[illegible]152, Zivan
3/16/96
[illegible]



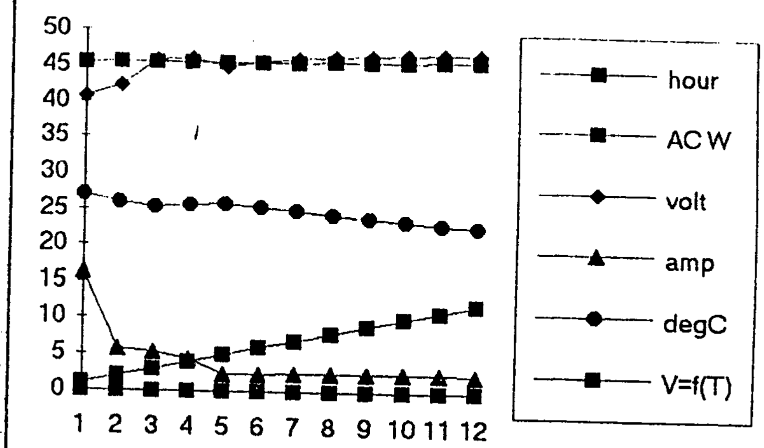
Charge on 3/9/96, 4152, Zivan



charge#	21					
17:46:18						
4/30/96						
seconds	3528					
Wh	0					
hour	AC W	volt	amp	degC	V=f(T)	2.51VPC
1	0	40.68	14.82	28.72	45.30442	
2	0	43.66	5.44	29.23	45.25484	
3	0	45	5.44	29.85	45.19458	
4	0	43.03	3.46	30.48	45.13334	
5	0	42.53	2.35	30.27	45.15376	
6	0	42.92	2.37	29.74	45.20527	
7	0	43.22	2.38	29.13	45.26456	
8	0	43.51	2.38	28.51	45.32483	
9	0	43.8	2.39	27.91	45.38315	
10	0	44.08	2.39	27.36	45.43661	
11	0	44.34	2.4	26.84	45.48715	
12	0	456.69	0.15	232.62		
charge#	22					
6:59:07						
5/11/96						
seconds	24039					
Wh	0					
hour	AC W	volt	amp	degC		
1	0	41.89	16.95	17.23		
2	0	42.06	7.46	18.31		
3	0	43.21	5.37	19.09		



charge#	1				
19:50:46					
9/14/95					
seconds	41200				
Wh	0				
hour	AC W	volt	amp	degC	V=f(T)
1	0	40.72	16.35	27.08	45.46382
2	0	42.27	5.75	25.98	45.57074
3	0	45.88	5.38	25.38	45.62906
4	0	46.19	4.43	25.68	45.5999
5	0	45.07	2.4	25.86	45.58241
6	0	45.79	2.41	25.41	45.62615
7	0	46.19	2.42	24.9	45.67572
8	0	46.47	2.42	24.37	45.72724
9	0	46.65	2.43	23.88	45.77486
10	0	46.8	2.42	23.45	45.81666
11	0	46.93	2.43	22.98	45.86234
12	0	46.98	2.41	22.68	45.8915



Test Report: American Monarch, 60 V Battery Charger

2 November, 1996

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: William R. Warf
Pacific Electric Vehicles

This Project is sponsored by DARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

Test Report: American Monarch 60 Volt Battery Charger

Scope:
An American Monarch Charger was obtained for the 60 V four wheeled City-el constructed on chassis 4138. This report provides brief testing results and observations regarding the performance of this battery charger.

Energy Use:
The vehicle system achieved AC energy use (measured by the Hydria AC kW-h meter) of 262 AC W-h per mile average, and 202 AC W-h per mile best. Please refer to our report "Testing Notes, Persport #3" dated 11/1/96 for a description of the vehicle system.

Test Results
A charge of the battery pack was recorded on 23 August, 1995 using a Cruising Equipment kW-h meter and a lap top computer. The Cruising Equipment meter allowed recording time series Current, Voltage, and Time. The record of the charge is attached. Batteries used in this vehicle are DC-78 Trojan batteries, which have provided 25 A-h at about the 1 hour rate. The charger has given good service, and the batteries still in service.

The charger provides a peak current of 15 A. The current is reduced in 1 Amp increments as the voltage increases. When the gassing point is detected the charger switches into a constant current mode and sets a two hour timer.

As installed, the American Monarch charger usually sensed the gassing point as 76-77 Volts (2.53- 2.56 volts per cell or vpc) depending on temperature, and reduced the current to 4 Amps. It continued to charge at 4 Amps for two hours. The attached plot is believed to be representative of a typical charge.

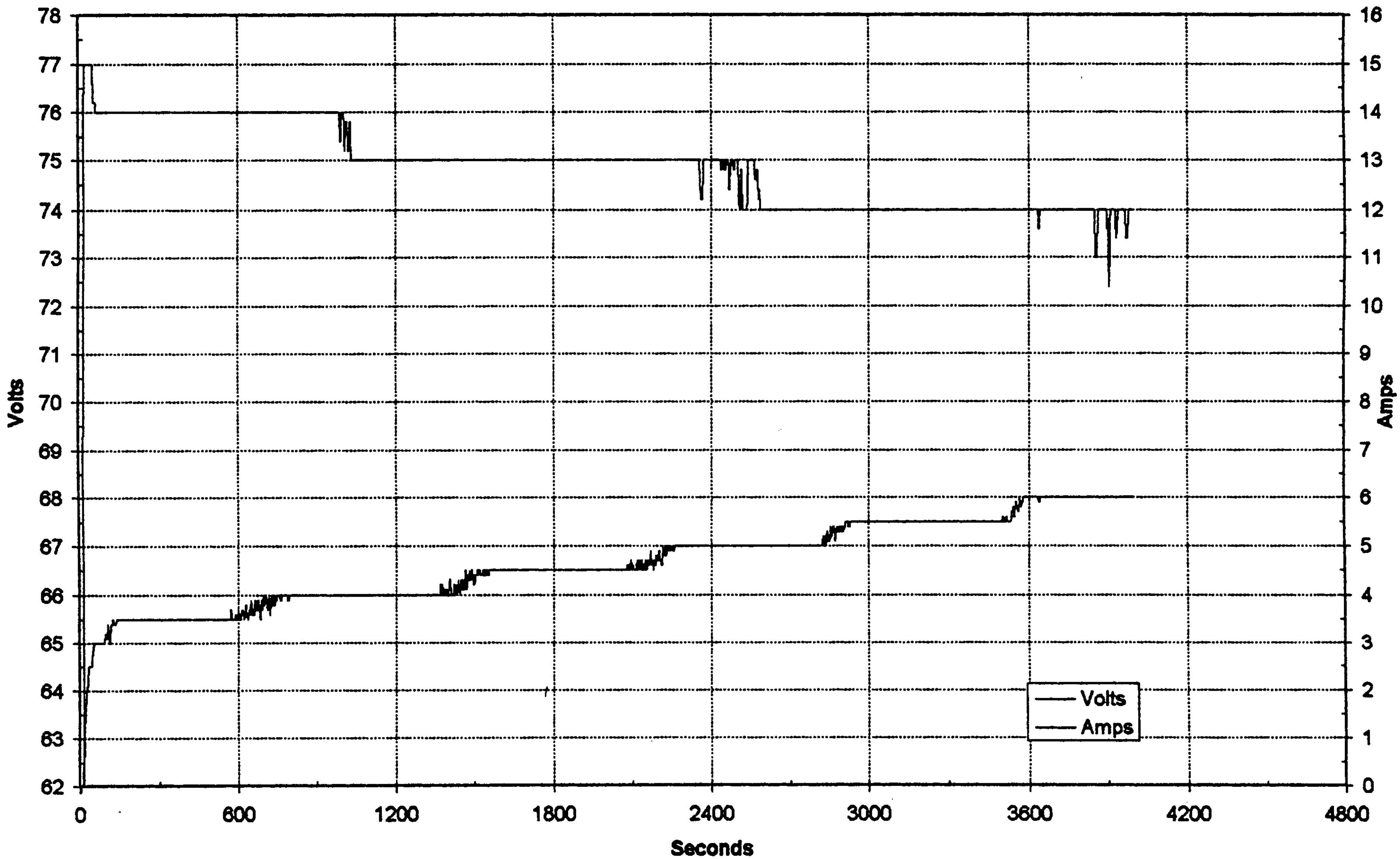
The stabilized open circuit voltage was usually 64 V in cool weather, and 66 V in warmer weather. Stabilized Specific Gravity readings taken on 23 August, 1995 gave readings from 1.26-1.28, showing the batteries were undercharged. This is consistent with the open circuit voltages observed.

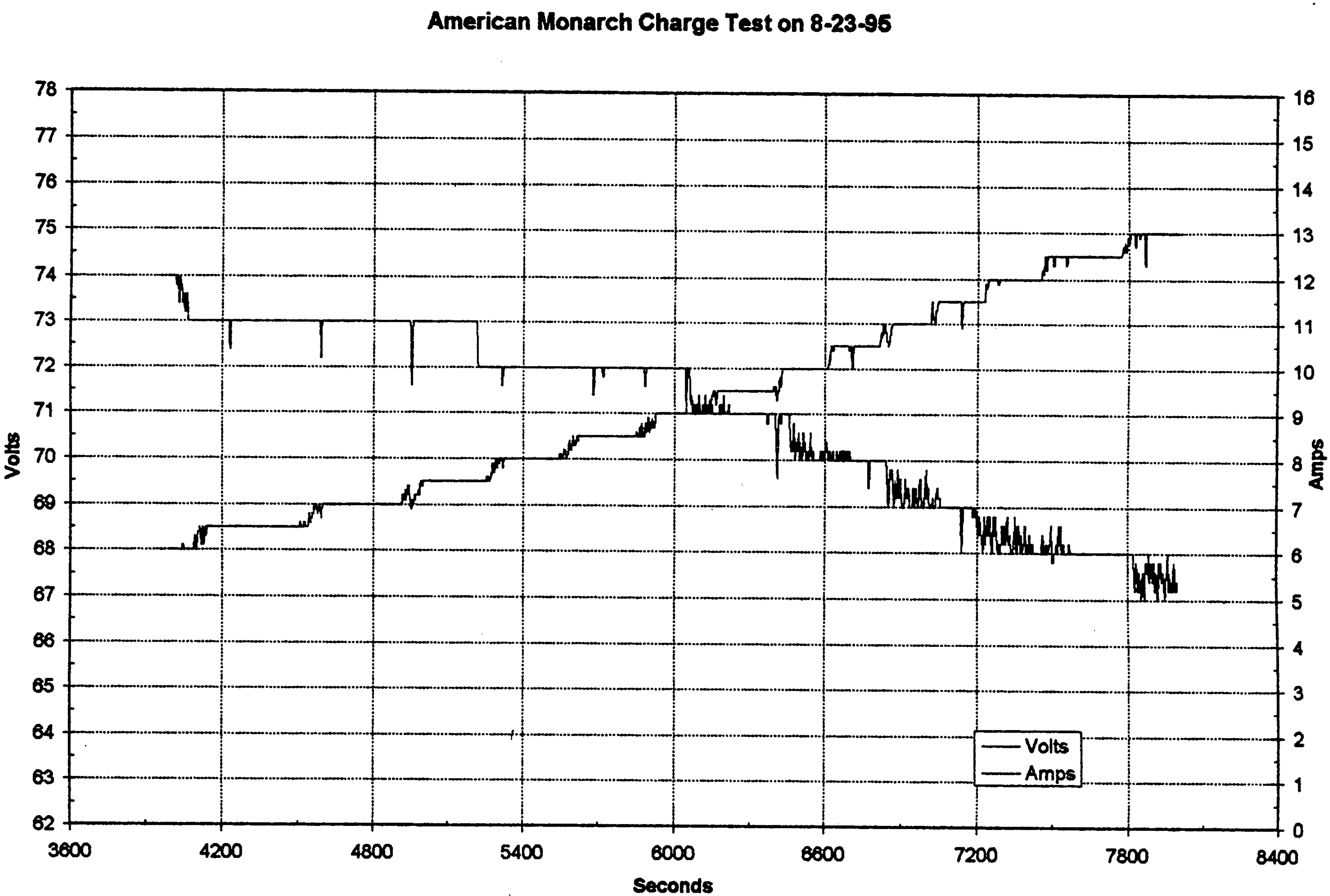
The charger can be left connected to the vehicle to keep the batteries charged. It will turn itself back on periodically and go through a charge cycle. Water use of this charger was not excessive.

The charger weighs 38 lbs and is not considered appropriate for an on board NEV charger. It's power efficiency is estimated using a Hydria AC Watt Meter to be about 80%, which is better than the 67% power efficiency of the City-el charger. This improvement is believed to be because of a better design for the ferro-resonant transformer.

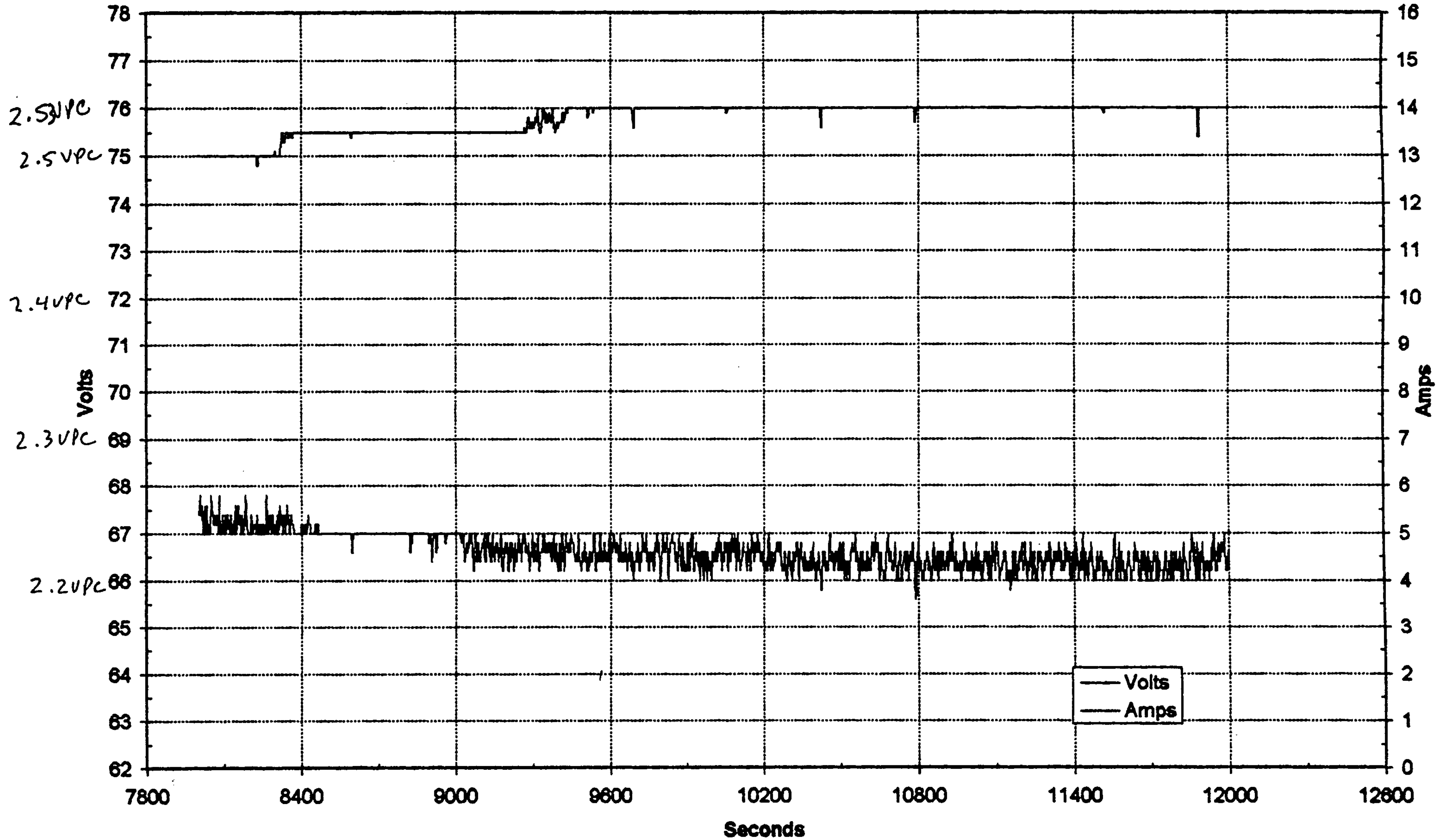
The American Monarch charger cost $777 in 1994. It has a specific power of 57 W/kg and cost $0.8/W.

American Monarch Charge Test on 8-23-95

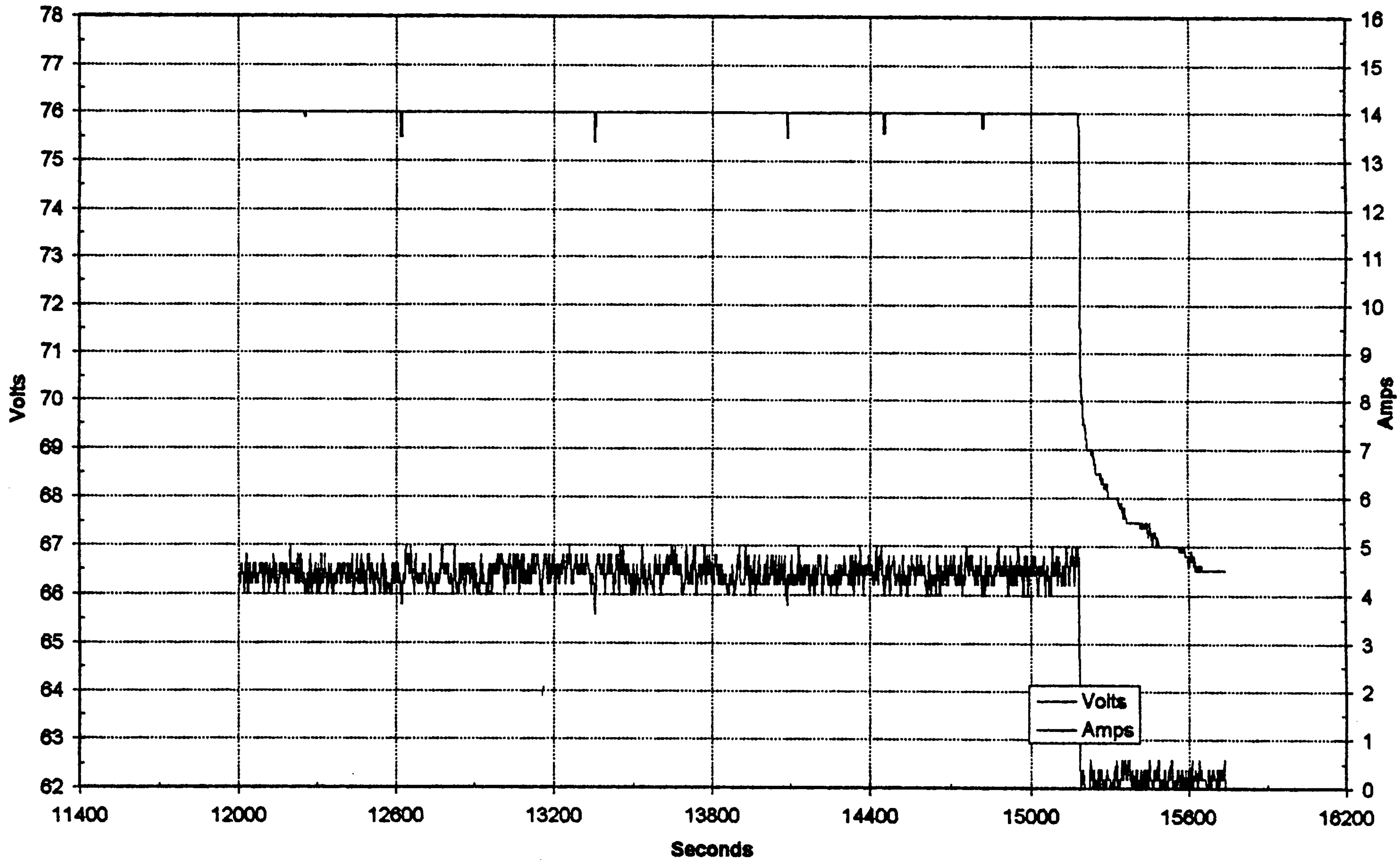



American Monarch Charge Test on 8-23-95
78
77
76
75
74
73
72
71
70
69
68
67
66
65
64
63
62
Volts
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Amps
3600
4200
4800
5400
6000
6600
7200
7800
8400
Seconds
Volts
Amps

American Monarch Charge Test on 8-23-95



American Monarch Charge Test on 8-23-95



Mirabor Charger Evaluation.

18 November, 1996

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

TEST REPORT: .Mirabor Charger Evaluation
Prepared by: Lance Atkins, Pacific Electric Vehicles, 18 Nov. 95

Purpose: This testing was done to continue the evaluation of the Mirabor modular charger. The Mirabor charger is unique since it has an individual charging module for each battery. Previous testing done by Pacific Electric Vehicles (PEV) has indicated that a charger of this type might improve battery life by eliminating the over or under charge that individual batteries receive when a long string of batteries is charged with a bulk style charger. For those unfamiliar with the Mirabor charger, copies of Mirabor's promotional literature and specifications are included in the appendix. This charger was first tested in January and the results were reported in the report titled Initial Mirabor Charger Test on the City-el. A copy of this initial report is included in the appendix. If the reader is not familiar with the initial report, it will be helpful to read the report before continuing. The initial report left several unanswered questions which have been largely answered during this test.

Scope: While it is expected that a modular charger like the Mirabor will improve battery life by charging each individual battery optimally, this test did not attempt to prove this. This test was performed primarily to evaluate the operation of the Mirabor charger and to compare the charge profile for each battery with the charge profile each battery received under a bulk charger. Two bulk chargers were used for comparison purposes. The heavily tested standard City-el charger was used as the baseline bulk charger and the Zivan charger was used as a higher rate bulk charger comparison. The Zivan charger is not thoroughly evaluated here. This is done in a separate report using some of the data obtained during testing for this report. All three chargers were tested on City-el 4126 with its pack of 3 Trojan SCS 225 batteries.

Results: Following the initial test, it was discovered that the pulse frequency of the Mirabor charger was causing the City-el Data Acquisition System (DAS) to read improperly. For this reason, a Fluke Hydra was used to obtain the test data. Unfortunately, this did not solve all of the instrumentation problems that were encountered during the initial test. Again, only rough values for AC and DC energy were possible which made any efficiency calculations quite inaccurate. Electrical noise was quite evident in all of the Mirabor charger data and was apparent in both the City-el and Zivan charging current data. The thermocouple noise is definitely induced noise from the charger, but the voltage and current noise is probably due to the switching frequencies of the chargers. For this test, the average of the data was taken as the correct value except during charging phase transitions where the moving average is obviously incorrect. Due to time constraints, this test was designed to run unattended and so some of the measurements made during the initial test have not been re-measured here.

The prototype Mirabor charger showed signs of value in spite of numerous problems during the test. After problems with the temperature sensors during the initial test, Craig Ranta of Mirabor re-tested the module firmware to discover that a coding error caused the modules to use a gassing voltage that was too low. In addition, persistent problems with noise on the Mirabor temperature sensors has made evaluating the temperature compensation very difficult. At this point, aside from the low voltage, it looks like the temperature compensation of the gassing voltage sort of works in spite of the coding error and noise. The modules do a very good job of starting and ending the over charge phase at the optimum time for each battery. The gassing voltage is also adjusted based on the individual temperature of each battery. The City-el charger shows very good agreement with the requested pack gassing voltage but leaves one battery above the optimum voltage and one below it. No adjustments were made for the differences in temperature either. Although the voltage and temperature differences are small in this case, the effect would be much more noticeable on a larger pack. Aging batteries caused the Mirabor modules to have very different over charge times. Module 1 lasted 2 hours, module 2 lasted 7 hours, and module 3 lasted 8 hours. While this did a great job of highlighting how the charger handles batteries with very different states of charge, it is an extreme case. The batteries have aged enough that to maintain the gassing voltage, it takes slightly more than the 3.29 amps which the modules have to drop to before they switch to the equalizing phase. This causes the modules to hang in the over charge phase until battery impedance changes enough for the current to reach 3.29 amps. Two previous tests had to be aborted because this problem was even worse. In a real disappointment, it was discovered that the 3 hour timer for the equalizing stage does not start individually but starts only after all modules have reached the equalizing stage. This left battery 1 on equalize for 9 hours. It's too bad that this is not done individually like the rest of the charging profile is.

The test procedure for this test left the batteries at the same state of charge for the beginning of each individual test. This means that each charger had the same task to perform. The Mirabor charger brought the average specific gravity (SG) up to 1.295 during the 13 hours of its test. This is significantly higher than the average of 1.270 recorded during the initial test and in measurements made between the two tests. The excessively long overcharge times are to blame for this discrepancy. The 1.270 SG does not really indicate of a fully charged pack, but the low gassing voltage resulting from the coding error is probably to blame. The City-el also reaches an average SG of 1.295 mostly due to a very long equalizing phase during its 10.25 hour charge. The Zivan charger brought the SG up to 1.281 during the 6.5 hours it was operating. The SG would have been much lower had the float phase of this charger been set at a more reasonable level. The float is set so high presently that the 1.5 hours of float phase did some equalizing.

These tests have shown that it is possible to design a modular charger which charges each battery optimally. It is apparent that the Mirabor charger could use some further refinements, but it is very close. Although testing the system on the three batteries of a City-el pack reduced the complexity and expense of the testing, it is unfortunate that it could not be tested on a larger pack where the benefits would have been more apparent.

Solutions to Initial Mirabor Charger Test Problems.

During the initial tests on the Mirabor charger several problems were identified which needed to be solved before the next round of testing was begun. These problems are reviewed and the solutions presented in the following paragraphs.

The City-el Data Acquisition System (DAS) had some significant errors in the charge current reading. At the time, it was assumed that a recalibration of the shunt would solve the problem. After the recalibration though, the problem still persisted. At this point, it looks like the pulse frequency of the charger is causing problems with the reading of the DAS. This has happened before when the DAS was used with other pulse type chargers, but it was more noticeable in those situations. Since the DAS current reading is inaccurate, DAS data was not used for this testing. A Fluke Hydra was used in place of the DAS.

The original installation of the Mirabor charger required that the negative lead of module 3 be lengthened. This was blamed for a 0.2 volt difference between the battery voltage as measured by the Fluke multimeter and the Mirabor control panel. Since the DAS was no longer being used, it was possible to shorten the lead to its original length. Due to time constraints, this round of testing was setup to run unattended and no readings were done to verify that the shortened lead solved the problem. Informal checks during the initial start of the test indicate that some of this problem still remains. It may be due to measurement problems of the pulsed voltage rather than the lead length.

The temperature sensors for the Mirabor charger had significant noise problems during the initial tests. This was attributed to the extra length of sensor wire that was bundled near the AC power lines and the routing of the temperature sensor lines. The extra wire was removed after confirmation from Mirabor that this was not a problem. Several other routing methods were tried as well. There was some improvement, but the problem still persists.

Due to the temperature sensor problems, it was impossible to verify the temperature compensation of the gassing voltage during the last test. After reading the initial report, Craig Ranta of Mirabor sent the following information which has been excerpted from the complete FAX. The complete FAX is included in the appendix.

> *When I saw the data about the temperature compensation being screwed up, I went back and re-tested your version of module firmware. It looks like there is a coding error which causes the modules to hold the batteries at the wrong gassing voltage. In my test unit, the temperature compensations seems to work, but the gassing (overcharge) voltage is too low. I'll troubleshoot this as time permits.*

Data from this test seems to support this. The requested temperature compensation for the gassing voltage was U=6cells*(2.625V/cell-5mV/C*(T-25C)). During the initial test the gassing voltage was 15.7 volts at about 13 degrees Celsius. The equation would give 16.11 volts at that temperature. During this test, the temperature was about 37 degrees Celsius and the gassing voltage was about 15.25 volts. The equation gives about 15.4

volts. So it seems that the temperature compensation sort of works, but between the coding error and noise, it is not possible to evaluate the temperature compensation.

There were problems with the Cruising Equipment DC Amp hour meter during the last test which made energy efficiency calculations impossible. This time, it was hoped that the time series data from the Fluke Hydra could be used to calculate the DC energy and that this would be compared with the AC energy recorded from the Hydria meter. Unfortunately, noise problems with the Fluke Hydra made calculations of DC energy very uncertain. Furthermore, there was insufficient time to troubleshoot interface problems between the Hydria AC kWh meter and the Fluke Hydra. As a result, energy efficiency calculations are still not possible.

Test Setup.

This test was conducted on City-el 4126 which was equipped with three Trojan SCS 225 batteries. This was the same vehicle used for the initial test. The City-el charger used was the one originally supplied with the vehicle. The Zivan charger was removed from its test vehicle and used on City-el 4126 for the purposes of this test.

Since the City-el DAS system was not working properly with the Mirabor charger, a Fluke Hydra was used to collect the test data. The Hydra is essentially a multi-channel multimeter with the ability to record readings on a periodic basis. These readings are stored in a proprietary file format on an SRAM card. The file can be converted to CSV format for use in the PC using the supplied conversion software. This is significantly different than the City-el DAS which makes continuous readings and reports an average on a periodic basis to an attached PC. The Hydra has the ability to take the periodic reading, insert it into a user defined mX+b formula, and report only the result. This makes it possible to read milivolt readings of a shunt but report amps instead of milivolts. This feature was used to reduce the amount of post processing required. A wide variety of thermocouple types are preprogrammed into the Hydra. This makes it very easy to use thermocouples. The channel is configured for temperature and the proper thermocouple type is selected. The resulting reading is automatically displayed in degrees Celsius or Fahrenheit at the users discretion. The unit supports 4 wire thermocouple setups, but the simpler 2 wire setup was used for this test. Virtually all sensor connections to the Hydra are made through a universal input module which is essentially a large plug with labeled screw terminals inside for the sensor lines. It supports up to 21 channels, but only 11 channels were used for this test.

A custom sensor harness for the Hydra was installed in City-el 4126. A description of each channel's sensor connections follows. Channel 1 measured battery 1 voltage. This is the left most battery in the City-el. The connections were made to the positive terminal of the battery and the positive side of the current measuring shunt which was attached to the negative terminal of the battery. Channel 2 measured the current from the Mirabor module 1 connected to battery 1. A 50 mV at 25 amps shunt was used. The sensor lines were connected to the appropriate shunt terminals. Channel 3 measured temperature in degrees Celsius for battery 1. A type K thermocouple was used for this measurement.

This was a Fluke thermocouple intended to be used with the Fluke multimeter temperature measuring attachment. Because of this, it was necessary to add wire from the termination plug of the thermocouple to the Hydra universal input module. Since the Hydra compensates for the thermocouple action which occurs at the connection point of the input module, there may be a slight error in the temperature measurement. This is not expected to be a significant error. The thermocouple was taped along with the Mirabor temperature sensor to the top of the battery using foam tape as insulation. Channels 4, 5, and 6 measured battery 2 voltage, current, and temperature with connections identical to battery 1 termination's. Channels 7, 8, and 9 measured battery 3 voltage, current, and temperature again with connections identical to those of battery 1. Channel 10 measured the pack voltage with connections made to the positive terminal of battery 1 and the negative terminal of battery 3. Channel 11 measured the bulk charge current for the City-el and Zivan chargers. The stock 3.33 mV/A City-el shunt was used for this measurement with connections made appropriately. The Hydra was configured to take measurements of all channels every 30 seconds. This setup was used to test all three chargers, and any irrelevant channels were ignored during analysis.

A Hydria AC kWh meter was used to obtain the total amount of energy used by the Mirabor and City-el chargers. It was not possible to use this meter with the 220V Zivan charger since the Hydria only works on 110V. Previous tests have shown the Hydria reads high by 10%. The reported total has been adjusted to account for this. The original plan for this test was to have the opticoupler output of the AC kWh meter connected to the totalizer channel on the Hydra. This would have allowed a more accurate value for AC energy used during charge and would have given an AC energy use profile for the charger. Unfortunately, this could not be made to work in the time available.

Test Procedure.

Testing started with the Mirabor charger, and 3 tests had to be run before a valid test could be obtained. The reasons for this are discussed later. Following this, the City-el charger was tested, and then after a several day delay, the Zivan charger was tested. During the delay, the vehicle was disconnected so that no discharge of the batteries, other than self discharge, would occur over this time. This made it possible to immediately continue testing following the delay.

City-el 4126 was fully charged at the start of each test. It was then driven over a 15.3 mile course at McClellan AFB. Due to road construction, the usual EV test route at McClellan was unavailable, but an alternate route was found and used for all tests. After returning to building 335, the vehicle was allowed to sit for 1 hour. Specific gravity measurements were then recorded for all cells. Following this, the vehicle was brought inside, and the Hydra was connected to the sensor harness and started. When started, the Hydra recorded the charging start time. The AC kWh meter reading was then recorded and the charger turned on. In most cases, the charger was left on overnight, and the Hydra recorded the information. (The Zivan charger test was the only one short enough to be done outside during the day.) The following morning the charger was turned off and the AC kWh reading recorded. The Hydra was then turned off and the file converted

to CSV format and backed up. One hour after the charger was turned off specific gravity readings were again recorded for each cell. Times for the switch to float charge and turn off were determined from the Hydra data file. The following table gives the time table of each test.

Mirabor Charger Evaluation Test Time Table

Charger	Mirabor	City-el	Zivan
Trip End	9-23-96, 13:48	9-24-96, 14:40	9-30-96, 6:56
Starting SG	9-23-96, 14:48	9-24-96, 15:40	9-30-96, 7:56
Charge Start	9-23-96, 15:55	9-24-96, 16:52	9-30-96, 9:03
Charger to Float	9-24-96, 5:04	9-25-96, 3:10	9-30-96, 13:49
Charger Off	9-24-96, 7:44	9-25-96, 6:56	9-30-96, 15:35
File Creation	9-24-96, 8:24	9-25-96, 7:12	9-30-96, 15:55
Ending SG	9-24-96, 8:44	9-25-96, 7:56	9-30-96, 16:35

Data was also taken on the Mirabor charger over a longer time period prior to this test. Two of those data sheets are included with this test to show the charger's earlier behavior. This is manual data taken before and after charge. It includes time, AC kWh, and specific gravity's of all cells. Some trip information is also included.

Data Considerations.

The large quantity of data acquired during this test has been graphed on 15 different charts. In order to aid readability of the following discussion, each chart is referred to by its alias rather than its lengthy full title. These aliases can be found on the lower left corner of each chart. The list of appendix contents at the end of this report includes the alias of each chart following the full title. All of the charts which contain charger profile data use a uniform 14 hour time base. This was done to make it easier to compare total charging time of each charger and to compare the duration of the individual charge phases for each charger.

The uniform time base also emphasizes the fact that each charger had the same task to perform. City-el 4126 was driven from a fully charged state over the same 15.3 mile course before each test. The average before-charge specific gravity shown in the SG Comp. chart clearly shows that the average specific gravity of the pack was very nearly the same at the start of each test. This indicates that the batteries were at the same state of discharge at the beginning of each charge. Each charger had the same amount of charge to return, but the rate and time to perform the task varied depending on the charger's profile.

A review of the charger profile graphs will show that the Mirabor charger had noise on all channels and that the current profiles for the City-el and Zivan chargers had noise. While it is certain that the temperature readings of the Mirabor charger are showing noise. It is not clear whether the current and voltage fluctuations are noise or switching pulses of the chargers which the Fluke Hydra is capable of reading. A more detailed test with an oscilloscope would be needed to determine this. Following noise problems during the last test, Craig Ranta of Mirabor makes this comment in his FAX, included in the

appendix "The modules are fairly noisy electrically, and the noise is very broadband (the switching frequency can vary from 15-40 kHz during a single AC line cycle)." For the sake of this test, it has been assumed that the average value of noisy channels represents the true value. This assumption may not be correct and would need oscilloscope data to validate. Also, the 10 minute moving average used on the charts is certainly incorrect during the transitions between charging phases.

Total DC Watt-hours delivered to the battery pack for each charger is shown in the DC Wh chart. This has been provided only as a rough estimate of DC energy. It is important to realize that these values are calculated from the noisy current and voltage data and are therefore not particularly accurate. Rough values for AC energy used are supplied on the City-el Charger Comparison spreadsheet. These values include all energy used by the charger including the float phase until it was unplugged. In the case of the City-el charger, this is 3 hours and 45 minutes of float phase. While this is not expected to be a large variation, it does affect the accuracy of the number. As mentioned previously, no AC energy measurements were done on the Zivan charger due to a lack of instrumentation.

Analysis of Bulk Charge (Constant Current).

Bulk charging is usually done at a constant current until the gassing voltage is reached. The bulk charging phase for the three Mirabor modules is nearly identical. As shown on the Current chart, they all charge at about 14 amps for just over 2 hours. A comparison of the Block 1, Block 2, and Block 3 charts indicates that module 3 may switch to over charge a few minutes ahead of modules 1 and 2. The Voltage chart shows that individual block voltages during this time are generally less than 0.1 volt apart. A temperature rise of about 2 degrees Celsius can be seen on the Temp Chart over this time period.

The City-el charger has a very similar behavior during this charging phase. The bulk charging current is shown to be about 12 amps on the City-el Profile chart. As would be expected, the lower charging current lengthens the time spent in bulk charge from 2 hours to just under 2.5 hours. Individual block voltages are again shown to be less than 0.1 volts apart on the City-el Volts chart. The City-el Temp chart shows a 2 degree Celsius rise during the first phase just like Mirabor charger.

An average bulk charge current of 22 amps is shown on the Zivan Profile chart. The Zivan charger is significantly faster than either of the other chargers. It has nearly twice the rate of the City-el charger. For this reason, one would expect the bulk charge to last about half the time of the City-el charger or 1.25 hours. In reality, this phase lasts less than 0.75 hours. The discrepancy between the expected time and the actual time may be due to the much lower gassing voltage which defines the start of the over charge phase. This is clearly shown on the Pack Volts chart. Differences between individual block voltages during this phase can hardly be distinguished on the Zivan Volts chart. The temperature rise shown on the Zivan Temp chart is again about 2 degrees Celsius.

Differences between the chargers during this phase are primarily bulk charging rate and the resulting time to the over charge phase. This is to be expected. Virtually any charger can do an acceptable job of the bulk charge phase. A modular charger like the Mirabor system only brings the ability to individually determine when each battery should be switched to the next phase. This is where a modular charger starts to make a difference.

Analysis of Over Charge (Constant Voltage).

The over charge phase is begun when the charger reaches a predetermined gassing voltage during the bulk charge phase. At this point, the charger holds the batteries at the gassing voltage and reduces the current as necessary. A careful review of the Voltage chart shows that the Mirabor modules make this transition several minutes apart. The gassing voltage is about 15.2 volts for modules 1 and 2 and about 15.3 volts for module 3. it is assumed that the 0.1 volt difference is due to a 3 degree difference in temperature shown on the Temp chart. Because of noise problems, it is difficult to be certain of this difference. The other problems associated with the temperature compensation were discussed earlier.

The City-el Profile chart shows that the City-el charger reaches this point when the pack voltage reaches 43 volts and the temperature is about 32 degrees Celsius. This agrees very well with the requested gassing voltage equation of U=18cells*(2.42V/cell-5mV/C*(T-26.67C)). This equation gives 43.08 volts as the required pack gassing voltage. When calculated for each battery, the voltage is 14.36 volts. The City-el Volts chart shows that only one battery is actually at this point. The other two batteries are at about 14.30 and 14.40 volts. Furthermore, differences in battery temperatures have not been considered. It may not be a significant problem on this pack of 3 batteries, but the problem gets worse as the number of batteries in the string increases.

The Zivan charger makes its transition to the over charge phase at about 41 volts. This voltage as shown on the Zivan Profile chart is a bit low compared to other chargers gassing voltages and probably accounts for the very close voltages shown on the Zivan Volts chart. Battery temperatures are around 23 degrees Celsius at the transition point.

The Mirabor charger shows very little increase in temperature during this phase as does the City-el charger. A sharp increase in temperature is show on the Zivan Profile chart towards the end of this phase. However, since the Zivan charger was tested outside, some or all of this temperature change could be due to ambient temperature changes.

The over charge phase ends when the current drops to a preset level. For the Mirabor charger, that level is 3.29 amps The Voltage chart shows that the time required varied significantly for the Mirabor modules. Module 1 was the first to switch to the equalizing phase. This is evidenced by the rise in the voltage which is released when the charger goes into the constant current equalizing phase. Module 2 switches to equalizing almost 5 hours later, and module 3 switches to equalizing 1.25 hours after that. While this shows the significant abilities of a modular charger, it appears to be an extreme case caused by an aging battery pack.

During the initial test, the modules finished the overcharge phase in about 2 hours and within minutes of each other. During this test, module 1 behaves nearly as before, but modules 2 and 3 take much longer. Battery age is believed to be the cause of the problem. Generally, as batteries age the current required to maintain a certain gassing voltage increases. Batteries 2 and 3 seem to have just reached the age where it takes slightly more than 3.29 amps to maintain the 15.3 volt gassing voltage. Changes in battery impedance after prolonged gassing may be responsible for the eventual change to the equalizing phase. This prolonged gassing affected the state of charge of the batteries and is discussed in detail later. It was this problem that required 3 tests before a reasonably valid test could be obtained. During the first two tests the modules hung in the over charge phase for very long periods of time. It seems that the extensive gassing of the batteries during the first two tests changed the battery impedance enough that during the third test the modules were finally able to switch to the equalizing phase.

This same phenomenon has been observed in a City-el charger tuned for Teledyne sealed batteries. After more than a year of use, the batteries were old enough that the charger would not go below the 3 amps required to switch to equalizing. The charger would stay in the over charge phase until the 10 hour bulk and overcharge time-out feature shut the charger off. This is shown in City-el DAS file D1466221.1SD, and recorded on the 8 Aug. 96 data sheet for City-el 4146.

The stock City-el charger addresses this problem by switching to the equalizing phase at about 9 amps. This is the reason that the City-el Profile and City-el Volts charts show a 3.5 minute long overcharge phase. DAS and other Neighborhood Electric Vehicle (NEV) program data show that batteries were almost always replaced due to significant range problems before the gassing voltage could not be maintained with 9 amps. This had the benefit of always operating the City-el capacity gage properly and by avoiding situations where the charger hung in the over charge phase.

The Zivan charger setting for switching to equalizing is about 4 amps according to the Zivan Profile chart. This setting works with these batteries both because the 4 amp setting is greater than the 3.29 amps of the Mirabor test and because the gassing voltage is much lower. The lower gassing voltage can be maintained with a lower current than what would be required for the Mirabor modules higher gassing voltage.

There are significant differences in how each charger handles the overcharge phase. Mirabor's modular charger shows benefits during this phase not only in its ability to individually start and stop the over charge phase for each battery but also in its ability to adjust the gassing voltage according to each individual batteries temperature. Because of the small number of batteries and the short duration of the overcharge phase, it is difficult to see the real benefit over the City-el charger. The improvement would be more noticeable on a longer string of batteries attached to a charger with a longer overcharge phase. It is also difficult to see any significant improvement over the Zivan charger because of the very low gassing voltage which tends to under charge the batteries. This is discussed in more detail later.

Analysis of Equalizing (Constant Current).

Once the current set point has been reached in the over charge phase, the charger switches to the equalizing phase which continues charging at the set point current. Generally this is a timed phase with times either set at a single value or by calculation using the time for the bulk and over charge phases. For the Mirabor charger, the equalizing time is set at 3 hours. Unfortunately, the Voltage chart shows that the Mirabor charger quits treating the batteries separately during this phase. The 3 hour timer does not start until all 3 batteries have reached the equalizing phase. This means that module 1 spends nearly 9 hours in equalizing mode. Electrolyte boiled out of the top of this battery during the test indicated that it had been excessively charged.

The City-el charger uses some sort of calculation for the time duration of the equalizing phase which in this case gave about 8 hours of equalizing. The City-el Profile chart also shows that the current continued to drop from its set point of 9 amps to about 5 amps during the equalizing phase and that the voltage increased from 43 to 47 volts. It is assumed that battery impedance changes due to the sharp rise in temperature and other chemical changes associated with gassing are responsible for the continued drop in current. Impedance changes are also assumed to be responsible for the sag in the voltage towards the end of equalizing. It is also possible, however, that this behavior is due to some sort of power or transformer characteristic of the charger. NEV DAS data shows that current tends to rise and voltage decreases as the batteries age. As mentioned earlier, this setting has the benefit of self adjustment based on the age of the batteries. Experience with battery life during the NEV program, though, indicates that this may be a bit too rough on the batteries.

The Zivan charger was set to maintain about 4 amps during equalizing and the duration was 2.5 hours. The Zivan Profile chart shows that the voltage was released and that the temperature rose about 10 degrees Celsius. As stated earlier, it is not known how much of this is due to ambient temperature changes while testing outside. Voltage rose from 41 volts to about 46 volts.

The Mirabor charger would have shown a real improvement here if each of the batteries had continued to be treated individually. Unfortunately, it over equalizes battery 1 and to some extent battery 2. Both the City-el and Zivan chargers appear to have a slightly high equalizing current which results in very high equalizing voltages and perhaps excessively vigorous gassing. The benefits of the higher current setting have been mentioned earlier.

Analysis of Float Charge.

After the equalizing time has expired, the charger goes into a float charge phase. This is also known as a trickle or maintenance charge. The float charge is usually specified with a temperature compensated float voltage, but can also be specified as a constant current. Information was not available on the Mirabor float charge specification, but it appears to charge at about 0.5 amps and maintain a voltage of 39 volts.

The City-el charger has a temperature compensated float voltage of U=18cells*(2.22V/cell-5mV/C*(T-26.76C)). A review of the City-el Profile chart will show that the voltage is nearly the calculated 38.7 volts for 40 degrees Celsius. It can also be seen that the voltage rises as the temperature of the batteries falls. The current which goes to zero until the pack voltage falls to the float voltage rises to about 0.5 amps to maintain the voltage.

The Zivan charger has a current setting for its float phase. A look at the Zivan Profile chart will show that it is set at a fairly high 1.5 amps. This drives the float voltage up fairly noticeably.

Modular chargers don't provide much benefit in this phase and the more sophisticated temperature compensated voltage of the City-el appears to be the best during this phase.

Analysis of Final State of Charge.

Specific gravity's of all cells were taken after shutting off the charger. These specific gravity's are not fully stabilized specific gravity's, but they are close enough to provide a good indication of state of charge. The City-el Charger Comparison spreadsheet contains the individual SG readings for each cell. The averages reported at the bottom are charted on the SG Comp chart.

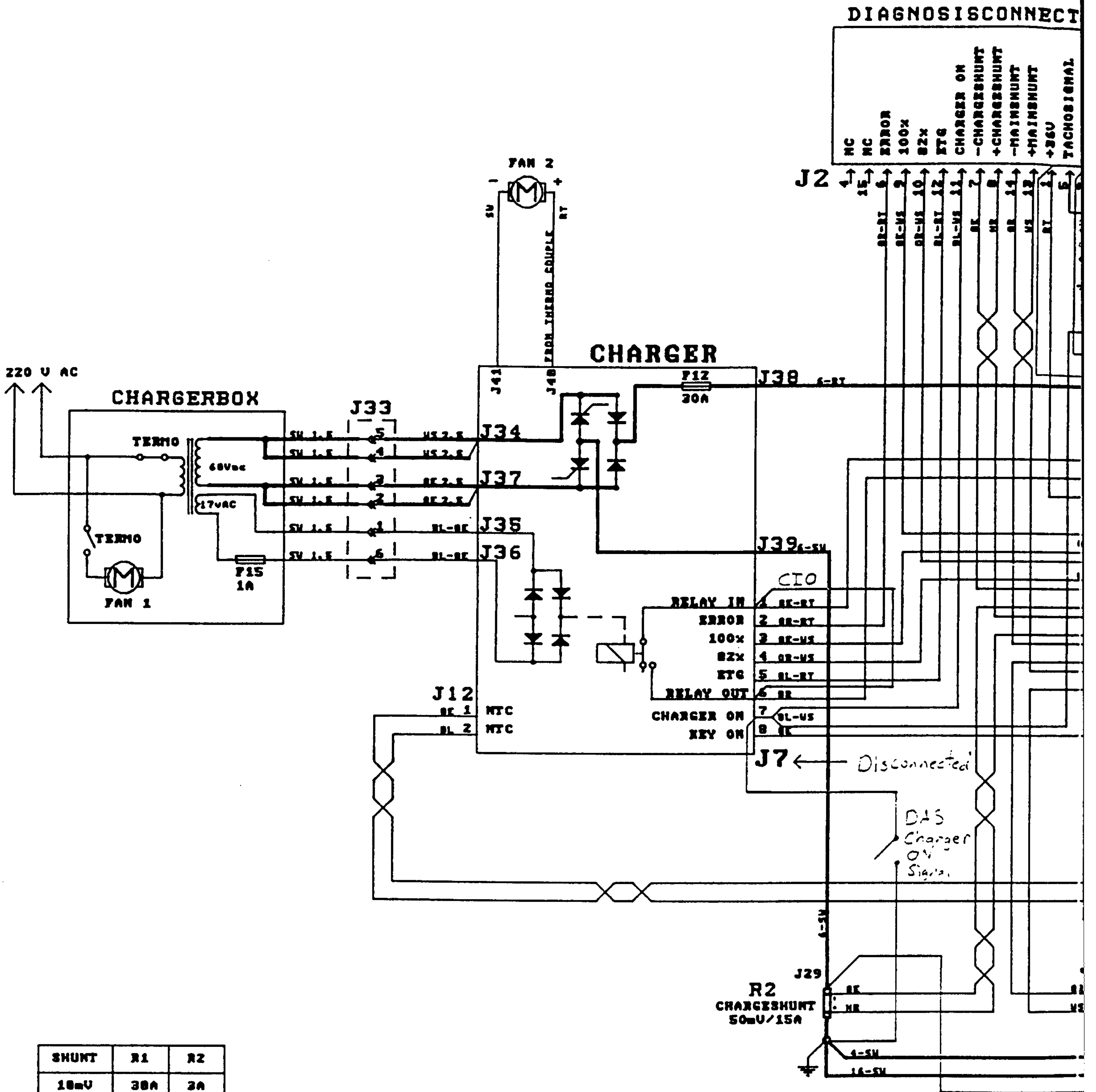
The Mirabor charger shows an average SG of 1.295 on the SG Comp chart. This indicates a very fully charged pack. As noted earlier, this was a result of problems which caused the charger to spend a very long time in the over charge phase. Results from the initial test and data shown on the data sheets recorded between times indicate that a more common average was 1.270. This would indicate that the batteries were not quite fully charged. A slightly higher gassing voltage or a longer equalizing time would probably solve this. Given the problems with the temperature compensation and the resulting low gassing voltage, the original setting may be correct, but the charger needs to actually give the requested profile.

The City-el charger also shows an average SG of 1.295 on the SG Comp chart. The very long equalizing time on the City-el charger is responsible for this very full state of charge. Although the long equalizing may be hard on the batteries it does tend to the keep the batteries at a more uniform state of charge.

An SG of 1.281 on the SG Comp chart shows that the Zivan charger did a good job of fully charging the batteries in a very short period of time. However, since the gassing voltage is so low and the float current so high, the state of charge is probably quite dependent on the amount of time spent in the float phase because the float phase is actually doing some equalization. The batteries would tend to be under charged if the charger were shut off immediately after completing the equalizing phase.

APPENDIX

Title of Appendix Contents:	Alias; Pages and Designation:
Mirabor Literature	3 page Brochure
Initial Mirabor Charger Test on the City-el	15 page Report
FAX from Mirabor	1 page FAX
Charger Comparison Test, Data Sheet	2 pages Data sheets
City-el Charger Comparison	1 page Spreadsheet
Average Specific Gravity of Cells in City-el 4126	SG Comp; 1 page Chart
Total DC Energy Input to City-el 4126 Battery Pack	DC Wh; 1 page Chart
Comparison of Pack Voltages for Chargers Used on City-el 4126	Pack Volts; 1 page Chart
Charge Profile for Mirabor Module 1 on Battery 1 of City-el 4126	Block 1; 1 page Chart
Charge Profile for Mirabor Module 2 on Battery 2 of City-el 4126	Block 2; 1 page Chart
Charge Profile for Mirabor Module 3 on Battery 3 of City-el 4126	Block 3; 1 page Chart
Comparison of Module Currents for Mirabor Charger on City-el 4126	Current; 1 page Chart
Comparison of Module Voltage for Mirabor Charger on City-el 4126	Voltage; 1 page Chart
Comparison of Module Temperature for Mirabor Charger on City-el 4126	Temp; 1 page Chart
Standard City-el Charge Profile of City-el 4126	City-el Profile; 1 page Chart
Comparison of Block Voltages for City-el Charger on City-el 4126	City-el Volts; 1 page Chart
Comparison of Block Temperatures for City-el Charger on City-el 4126	City-el Temp; 1 page Chart
Zivan Charge Profile on City-el 4126	Zivan Profile; 1 page Chart
Comparison of Block Voltages for Zivan Charger on City-el 4126	Zivan Volts; 1 page Chart
Comparison of Block Temperatures for Zivan Charger on City-el 4126	Zivan Temp; 1 page Chart
Also Available on Request:	
MIRABOR2.XLS	3.5 meg Excel 5.0 File
MIRABOR4.CSV	340k Comma Separated Variable File
MIRABOR5.CSV	311k Comma Separated Variable File
MIRABOR6.CSV	150k Comma Separated Variable File
D1466221.1SD	DAS Data File
City-el Service Sheet for City-el 4126 on 8 Aug. 96	1 page Data Sheet



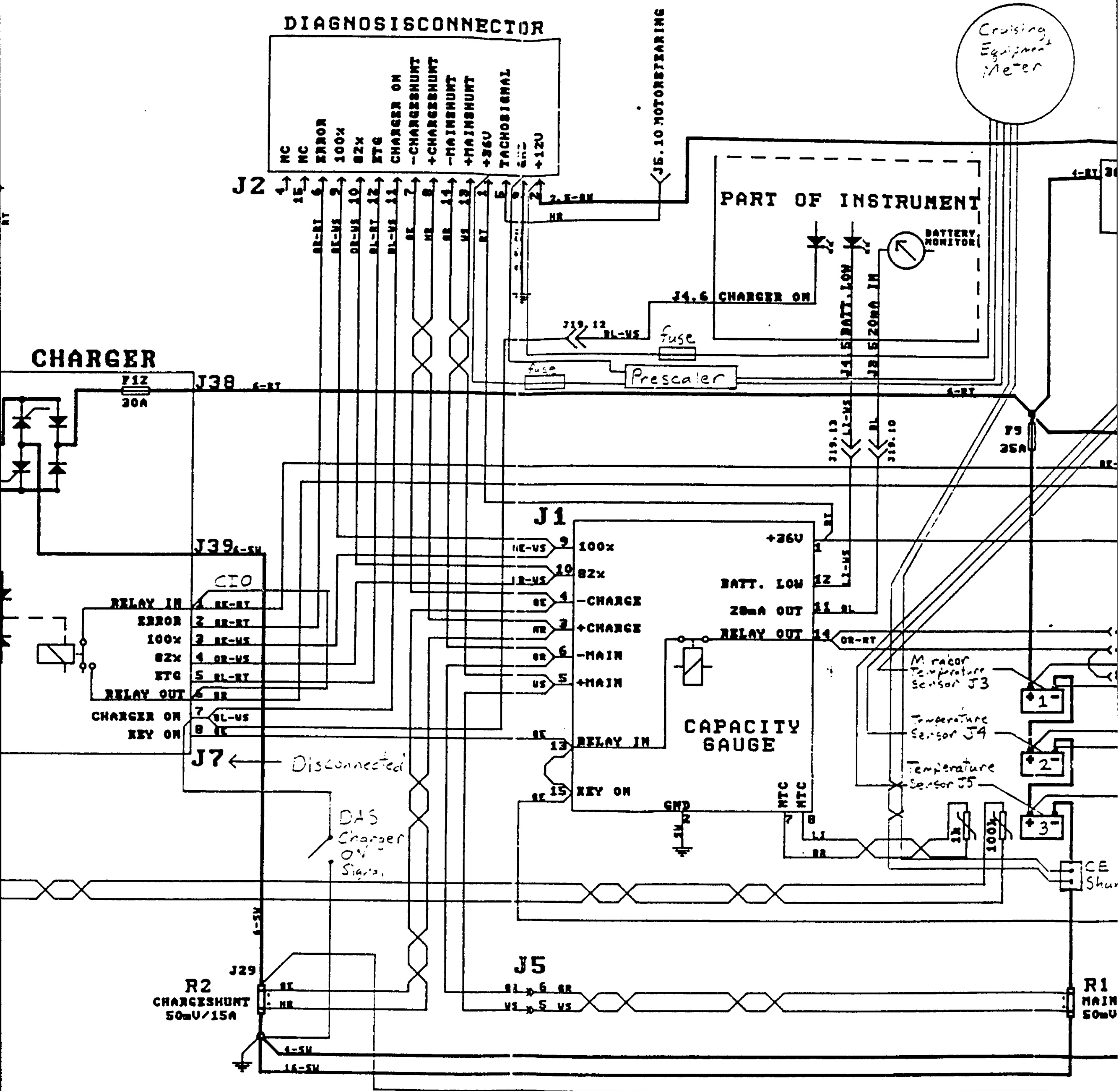
SHUNT	R1	R2
10mV	30A	3A
20mV	60A	6A
30mV	90A	9A
40mV	120A	12A
50mV	150A	15A

	ON	OFF
FAN 1	80 degC	65 degC
FAN 2	60 degC	45 degC

NTC THERMOCOUPLE		
TEMP.	CHARGER	CAPACITY
25 degC	100k ohm	1.00k ohm
15 degC	[illegible]50k ohm	1.60k ohm
0 degC	340k ohm	3.40k ohm
-10 degC	585k ohm	5.85k ohm

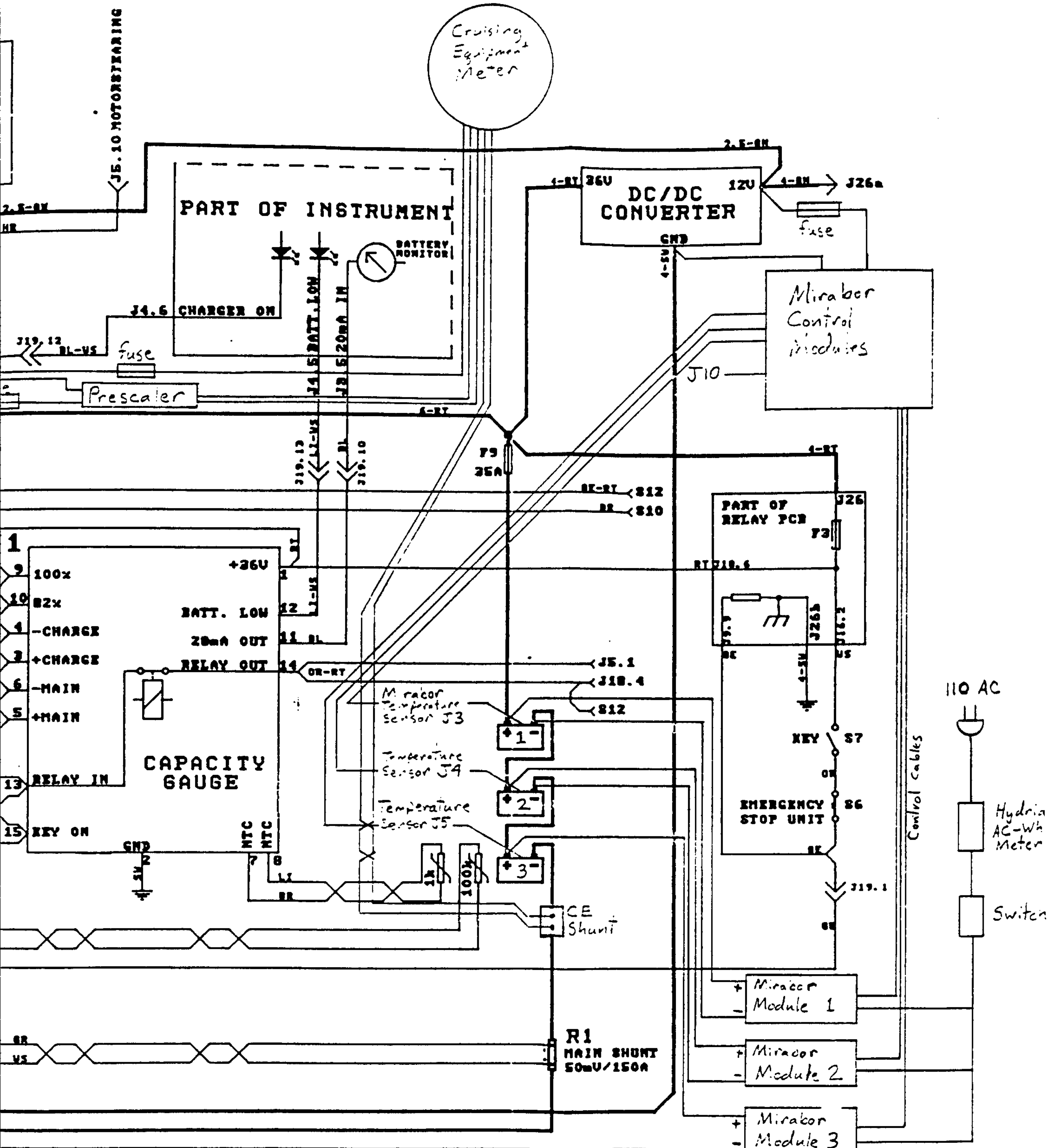
CIO = Charger Interlock Override

1



CityCom	Workshop Ma
Date: 920907	Model: Mirabor Cha
Prepared by: KJ	Subject: Charger and

Interlock Override



CityCom	Workshop Manual	Section/Group: 7/2	No.: 3.1-0 Page 1 of 1
Date: 920907 Prepared by: KJ	Model: Mirabor Charger Installation Subject: Charger and Capacity Gauge		Replaces: From VIN no.: 3006 To VIN no.:

Advance information

Mirabor Designs. **Power Modules**

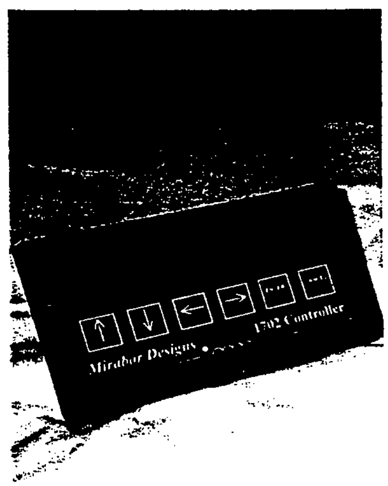
Modular battery charging system

- 12V charger modules
- For 12 to 384 volt lead-acid systems
- 20A maximum output
- 120/240 volt input, AC or DC
- 90% efficiency at 20 amps
- Extends battery life - no over or undercharging.
- Integrated fuel gauge function
- Fully isolated
- Temperature compensated
- Single point control of all modules
- Programmable for 12V gel cells or flooded cell lead acid batteries
- Remote breaker trip alarm option

Mirabor Designs is pleased to preview a new concept in EV lead-acid battery chargers, the Power Module 1701 system. Designed to address the shortfalls of existing EV battery chargers, the Power Module system provides a reliable solution for charging 120V and higher battery systems, even allowing 144V and higher systems to be charged from a 120V input. A full 20A of output is available for a 144V system with standard a 240V, 20A input. The Power Module system combines the latest high frequency power conversion techniques with a sophisticated charging algorithm and microprocessor control to maximize input power utilization and battery cycle life.

Smart.

All modules receive commands and send charging data to a single control point... the Mirabor 1702 controller, designed for under dash mounting. Power Modules communicate charging information to the controller on a low cost single twisted pair of wires. Power Modules also provide continuous battery voltage information when AC is removed, during the discharge interval, requiring minimal battery current.



Modular.

1 to 32 modules can be connected to a single controller for 12 to 384 volt systems. Battery charging and discharging status is monitored remotely with a 20 character x 2 line LCD on the 1702 controller. Easy connections to battery with standard automotive spade terminals.

Scalable.

Fact: Higher voltage EVs are more efficient. Losses are lower because currents and battery discharge rates are lower. You can upgrade any Power Module configuration to a higher voltage, just by adding modules, up to 32 total, making 120 to 144 volt charger upgrades easy.

Mirabor Designs

The future of power control

P.O. Box 7
Bothell, WA 98041-0
(206) 979-8372

Why modular battery chargers?

- Series chargers don't compensate for differences in battery characteristics

Lead Acid batteries are not the same, even new from the factory. Manufacturing tolerances and electrolyte imbalances cause slight capacity differences. Electrode porosity and surface area affect capacity and depend on processing temperatures. These differences can be magnified with aging and cycle life, resulting in undercharging batteries with higher capacity and overcharging batteries with lower capacity. Undercharging typically results in permanently reduced capacity. Overcharging results in gassing, heating and accelerated plate corrosion. Series chargers give an "average" charge to all batteries in the battery pack, resulting in non-optimal cycle life.

- Modular chargers can charge any voltage system

By using individual charger modules, controlled from a single point, the charging system can be scaled up and down with no special adjustments. Any system from a single auxiliary battery to a high voltage 32 battery system can be charged with ease. High voltage systems, typically with many smaller batteries, have additional potential for problems with battery charge balancing. Additionally, the currently popular non-isolated EV chargers are limited to battery packs of 120 volts or less from a 120 VAC source.

- Modular chargers provide integrated, smart monitoring

Each module can monitor its own battery individually, warning of fast discharging or slow charging characteristics. The slowest charging and the fastest discharging batteries can be identified and stored on each charge and discharge cycle. Total pack voltage or individual battery voltage can be displayed at the touch of a button. True fuel gauging is available with an external current shunt interface.

- Modular chargers are a safe, efficient, consumer friendly way to charge batteries

EV owners don't want to worry about their batteries! The fully isolated design and smart monitoring capabilities of the Mirabor 1701/1702 system provides a completely integrated battery management system which minimizes battery system maintenance.

Initial Mirabor Charger Test on the City-el

4 January, 1996

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: Lance Atkins
Pacific Electric Vehicles

This project is sponsored by ARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

TEST REPORT: Initial Mirabor Charger Test on the City-el.
Prepared by: Lance Atkins, Pacific Electric Vehicles, 1-4-96

Purpose.

Previous charger tests performed by Pacific Electric Vehicles (PEV) have indicated that when batteries are charged in long strings each individual battery does not necessarily get charged optimally. Based on this information a charger that charges each battery individually should provide optimum charging for each battery and therefore a longer life. In order to begin testing this idea and to evaluate the viability of this type charger, a prototype modular charger was obtained from Mirabor Designs. This system has individual charging modules for each battery. The power modules are controlled from and report information to a central control unit. In order to keep the initial complexity of the system down, the system was installed on the 36 volt battery pack of City-el 4126. This installation will also provide direct comparison between the Mirabor modular charger and the stock City-el charger.

Scope.

Installation of the Mirabor charger was completed on December 14, 1995. The batteries in the City-el had been discharged during a short trip previous to the completion of the installation. Once the installation was complete, instrumentation was added to the system and the test was begun. This test served primarily to verify operation of the charger. In addition, it provided a first look at the performance of the charger and information useful in refining future tests.

Results.

The Mirabor charger follows an IUI profile. The initial constant current phase ends when the charger detects the temperature compensated gassing point. Current is then lowered while keeping the voltage constant until the current reaches the equalizing current. Equalizing is then continued for 3 hours. The batteries did display some variation in voltage, but the current was also different for each battery. As a result, the batteries reached the same voltage for the last hour and a half of the charge. Specific gravity readings made 45 minutes after the end of charge indicate that all batteries were fully charged with almost all cells reading 1.275. This was not a fully stabilized specific gravity reading, but time did not permit a fully stabilized reading. Power efficiency for this prototype charger averaged 73%. Mirabor Designs states that higher efficiencies are possible.

A few problems with the installation of the charger did surface during the test. The Data Acquisition System (DAS) gave inaccurate charging current data. This is not uncommon and can probably be corrected by recalibrating the DAS with the Mirabor charger. It also appears that the extension of the negative lead of power module 3 has created a noticeable voltage drop. The extension was necessary to make the DAS and the capacity gage work. It may be possible to shorten the lead, but it will require some work to relocate the charge shunt and lengthen the DAS and capacity gage leads. There also appears to be a noise problem with the installation that is causing the Mirabor temperature sensors to malfunction. Moving some of the wiring may

remedy this problem. Finally, the Cruising Equipment meter DC amps and amp-hour readings do not work with the Mirabor charger. This made energy efficiency calculations impossible.

Future tests should be done after these problems are fixed. Those tests should focus on the temperature compensation and the voltage variation between the batteries. Each battery should have the voltage measured more accurately so that differences between the batteries are more apparent. Another DC amp-hour or Watt-hour meter should be found so that energy efficiencies can be calculated. Fully stabilized specific gravity readings should also be taken before and after each test. A direct comparison test between the Mirabor charger and the stock City-el charger would also be interesting as would a test with one of the batteries discharged much more than the others.

Test Setup.

The Mirabor Designs Charger was installed in the City-el using the instructions provided. Two modifications were necessary, however. A household light switch was used for the AC power line since a double pole switch rated for 15 amps at 120 volts could not be found. Module 3 had the negative lead extended to about 2.5 feet with 8 AWG wire. This was necessary in order to reach the shunt that makes the capacity gage and the Data Acquisition System (DAS) work. It is important to note that the lead is extended by about 5 more feet of metric 16 mm^2 wire in order to reach from the shunt to the battery. A schematic of the installation is included in the appendix. Only the termination's of the charger are shown accurately wire for wire. The connections between the charger components only show the general relation of the components. To simplify and speed the installation, the temperature sensors for each module were duct taped to the top of the battery between the posts. This completed the installation of the charger.

Several instruments were used during the test. The DAS system was used to closely monitor the charge profile of the charger on a minute by minute average basis. This system has been documented in the City-el Data Acquisition System User's Manual and the City-el Data Acquisition System schematic. In this particular installation, the DAS monitors the charging current of module 3 instead of the charging current of the whole pack. The rest of the system remains the same and monitors battery 3 temperature, pack voltage, and AC Watt-hours as reported by the Hydria AC-Wh meter. The Hydria meter was also used to monitor the AC power used by all three power modules. The Cruising Equipment meter was installed to monitor pack voltage, module 3 charge current, and the DC amp-hours of module 3. A Fluke 21 was used to check the voltage on battery 3, and a Fluke 79 was used at the charge shunt to monitor the charge current of module 3. All other test data was taken from the Mirabor control panel.

Unfortunately, the Cruising Equipment meter and the Mirabor charger are apparently incompatible. When ever the charger is plugged in, the Cruising Equipment meter reads 508 amps. This causes the DC amp-hour reading to increase at a furious pace and renders both readings useless. It may be that the pulse frequency of the charger and the sample rate of the meter are such that the meter gets erroneous data. As a result of this problem, energy efficiency was not available.

The DAS was set to take minute by minute averages and then the test was begun. Manual data was taken using the following procedure. Every 10 or 20 minutes the AC-Wh reading of the

DAS was written down followed quickly by the AC-Wh reading of the Hydria meter. This was done for two reasons. It provided a rough check on the accuracy of the DAS. This particular reading has been prone to noise in the past and subject to error as a result. More importantly this allowed the manual data to be synchronized with the DAS data. Following the Hydria AC-Wh reading, the Hydria AC power reading was taken. Data for module 3 temperature, voltage, current, and charging status were then taken followed by the module 3 voltage and current as reported by the two Fluke meters. The Cruising Equipment meter voltage was then recorded. Finally, the temperature, voltage, current, and charging status for modules 2 and 1 were taken from the Mirabor control panel. The pack voltage from the Mirabor control panel was also recorded. Manual data was taken until charging was complete. DAS data was continued until the system was unplugged.

Data Analysis.

The data from the test has been graphed on the following list of charts. These charts can be found in the appendix. The nickname given for each chart is used in the following discussion to aid readability by eliminating the bulky titles. The bulky titles were necessary so that the charts could be used alone and still provide the necessary information. The nickname for each chart can also be found in the lower left corner of each chart page.

Nickname	Chart Title
Voltage	Battery Pack Voltage Profile for 12-14-95 City-el Test of Mirabor Charger
Amperage	Power Module 3 Current Profile for 12-14-95 City-el Test of Mirabor Charger
Temperature	Power Module 3 Temperature Profile for 12-14-95 City-el Test of Mirabor Charger
Batt3 Voltage	Battery 3 Voltage Profile for 12-14-95 City-el Test of Mirabor Charger
Individual Blocks	Mirabor Reported Voltages and Currents for Each Individual Power Module
Power Efficiency	Power Efficiency for 12-14-95 City-el Test of Mirabor Charger

An examination of the Voltage and Amperage graphs shows that this charger follows the IUI profile that was requested by PEV. The bulk charge is a constant current phase which ends when the charger detects the gassing point. The voltage is then held constant until the current drops to the equalizing current. At this point, the voltage is released and the current stays constant until the requested 3 hour equalizing time has elapsed. It appears that the charger also has a float phase after the charge since the DAS shows a 1 amp current until the system is unplugged.

The Individual Blocks chart shows that there is some voltage variation between batteries as has been seen previously in the City-el 4135 Charger and Battery Test and the Solectria Force Charger and Battery Test. In this case though, the current for each battery is also different. As a result, the batteries reach the same voltage for the last hour and a half of the charge. It would be interesting to test the charger after deliberately discharging one battery more than the others. This would be an extreme data point but would highlight how the charger handles batteries with different states of charge. Individual battery voltages should also be measured with an instrument that provides better resolution than the Mirabor control panel. The tenth of a volt provided by the Mirabor control panel is not as fine as the one hundredth provided by the Fluke on the previous tests.

Since the Cruising Equipment meter didn't work, the efficiency of the charger was based on the power efficiency. Average power efficiency was 73%. A review of the Power Efficiency graph will show that the charger fluctuated between 70% and 80% efficient. This is about 20% more efficient than the stock City-el charger.

Specific gravity readings after charge indicate that the batteries were fully charged. The table Specific Gravity 45 Minutes After Charge, included in the appendix, shows that almost all cells reached 1.275. This is not a fully stabilized specific gravity reading, but time constraints prevented a fully stabilized reading. Furthermore, during future tests, the batteries should be disconnected after being charged so that the small discharge current from the City-el systems can be eliminated while the batteries stabilize.

There were several problems with the data during this test. Each problem, its suspected cause, and possible cure are described in the following paragraphs.

The Amperage graph shows that the DAS reported a current that was noticeably different from both the Fluke reading and the Mirabor reading. This is probably primarily due to a calibration error. The DAS has had problems in this area before and a recalibration of the DAS with the Mirabor charger will probably fix the problem. It is also possible that the pulse frequency of the charger is causing problems with the reading. This has happened before with other pulse chargers, but in those cases, the problem was obvious. A recalibration of the DAS should be done before anymore tests are performed.

A review of the Batt3 Voltage graph will show about a 0.2 volt difference between the battery voltage and the voltage reported by the Mirabor charger. This is not too surprising since the lead for that power module has been lengthened considerably. The cable size was quite large, but the negative lead was still lengthened by about 7.5 feet. It is possible to shorten the lead but not without finding a new location for the charge shunt and lengthening the twisted pair wires for the capacity gage and the DAS. Another possibility is to bypass the shunt for test purposes. This would require that battery current be measured by another method since the DAS would no longer measure the current. The capacity gage wouldn't work either. It is assumed that this problem is also responsible for the difference shown on the Amperage graph between the Mirabor reported current and the current reported by the Fluke at the charge shunt. This is also the problem with the Mirabor pack voltage shown on the Voltage graph.

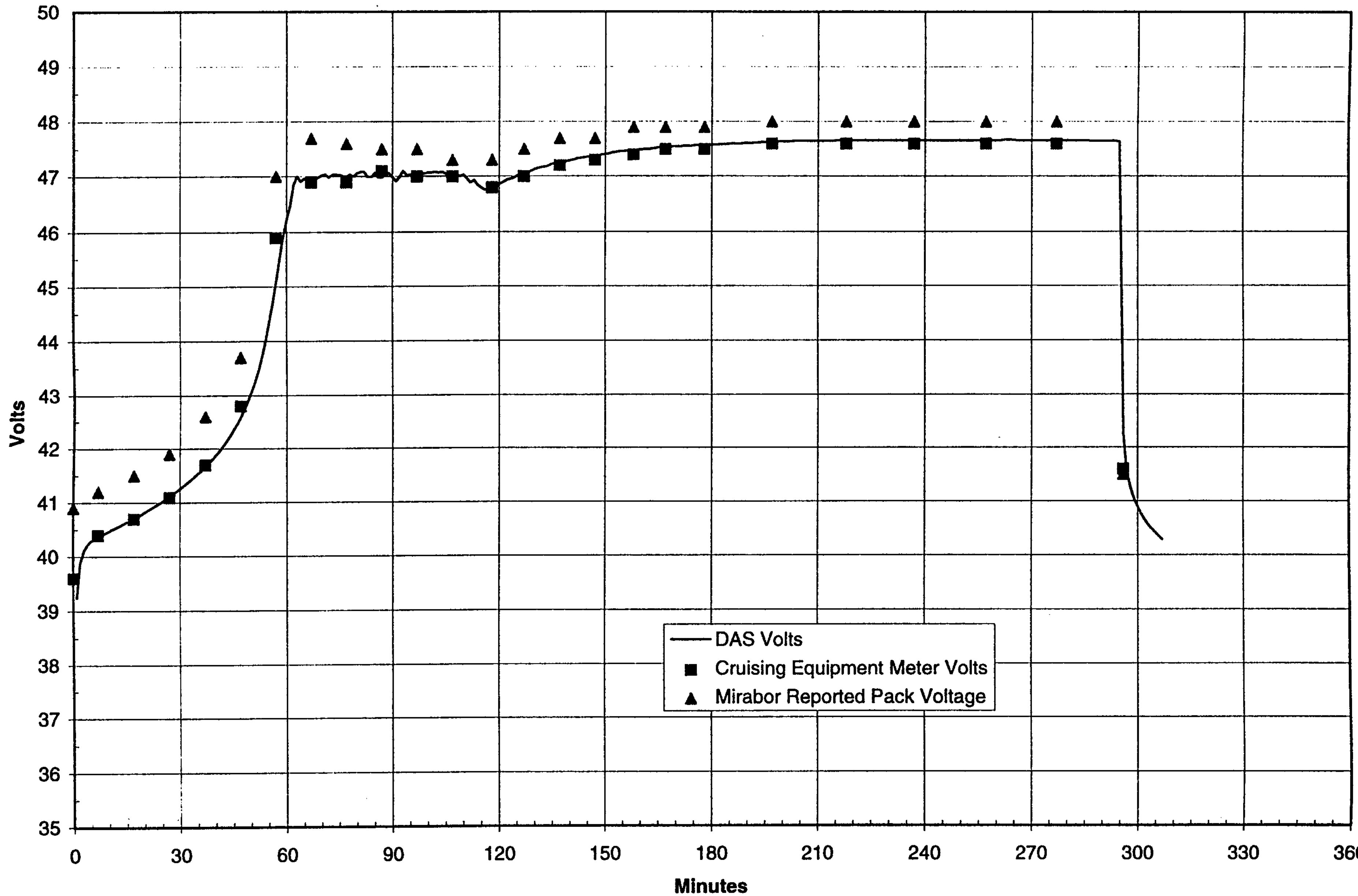
The Temperature graph shows a serious problem with the temperature sensor for the Mirabor charger. This problem is most likely a noise problem with the City-el installation. Currently, the data wires for the Mirabor charger are much too long for the City-el installation. This has resulted in a big bunch of wire stored near the AC power line. Stringing out or shortening that bunch of wire may well fix the problem. If that doesn't fix the problem, other wire routing schemes might. The temperature sensor problem has made it impossible to evaluate the temperature compensation of the charger. The requested equation was
$U = 6(2.625V/cell - 0.005V/C(T-25)C)$ for each battery.
Based on this equation, the gassing voltage should have been 16.14 volts with a temperature of 12 degrees C. The Mirabor modules acted as though the temperature was 25 degrees C with a

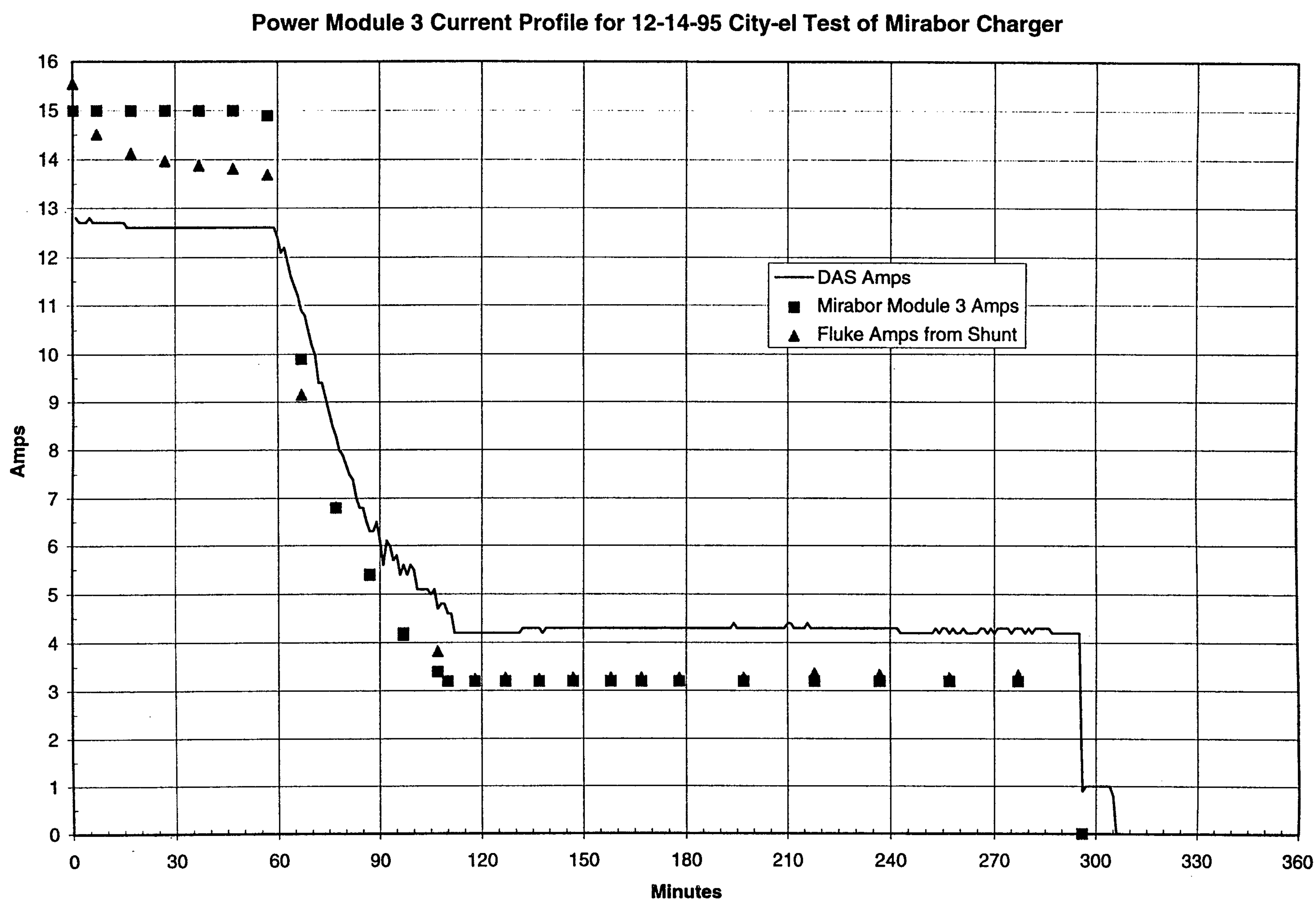
gassing voltage of 15.7 volts. It is impossible to tell whether this is because the modules defaulted to 25 degrees C or whether the temperature sensor fluctuation caused the problem.

Before future tests are run, the temperature sensor problem needs to be solved. A method for reducing the wire length on module 3 should be devised, and the DAS should be calibrated with the Mirabor charger. Once these things are fixed, a couple more tests should be conducted to test the temperature compensation of the charger and its behavior with batteries at very different states of charge. An instrument to measure DC energy input should also be obtained so that charger and battery efficiencies can be found. Each battery should be measured with the Fluke so that voltage differences between batteries can be more accurately determined. It would be helpful to have better current data for each module too, but this isn't absolutely necessary. Finally, the batteries should be disconnected after charge so that stabilized specific gravity readings can be obtained.

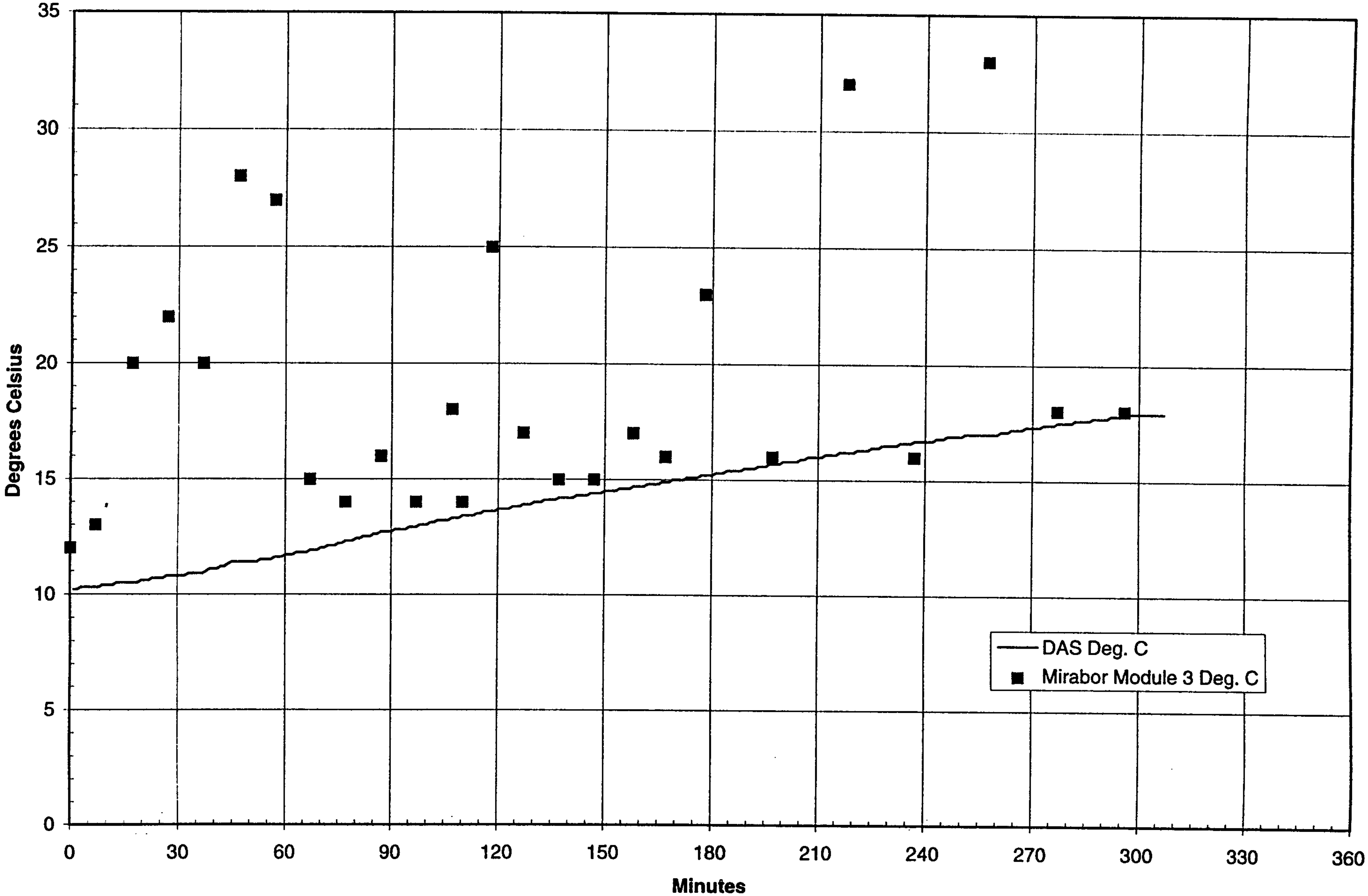
APPENDIX

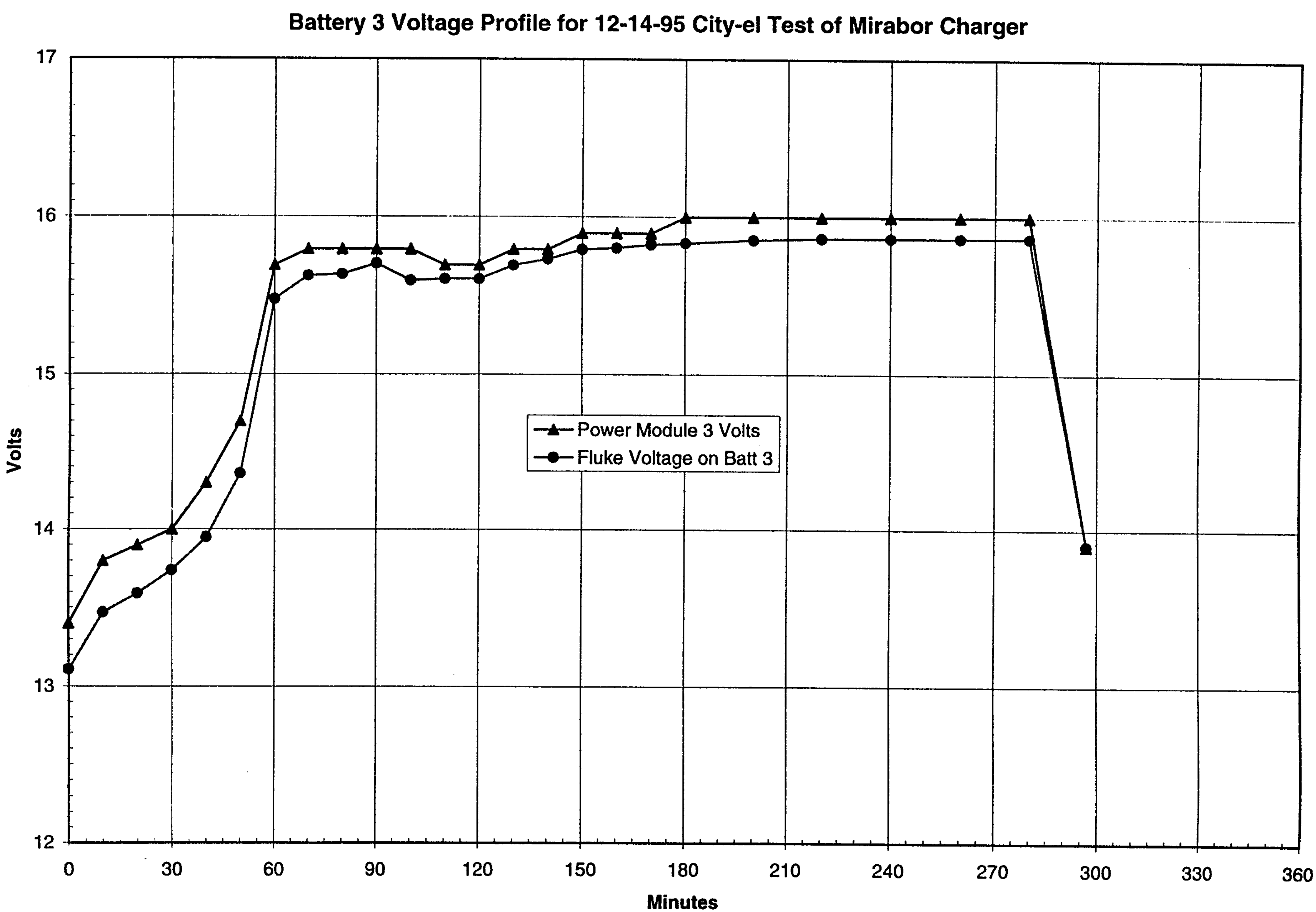
Battery Pack Voltage Profile for 12-14-95 City-el Test of Mirabor Charger



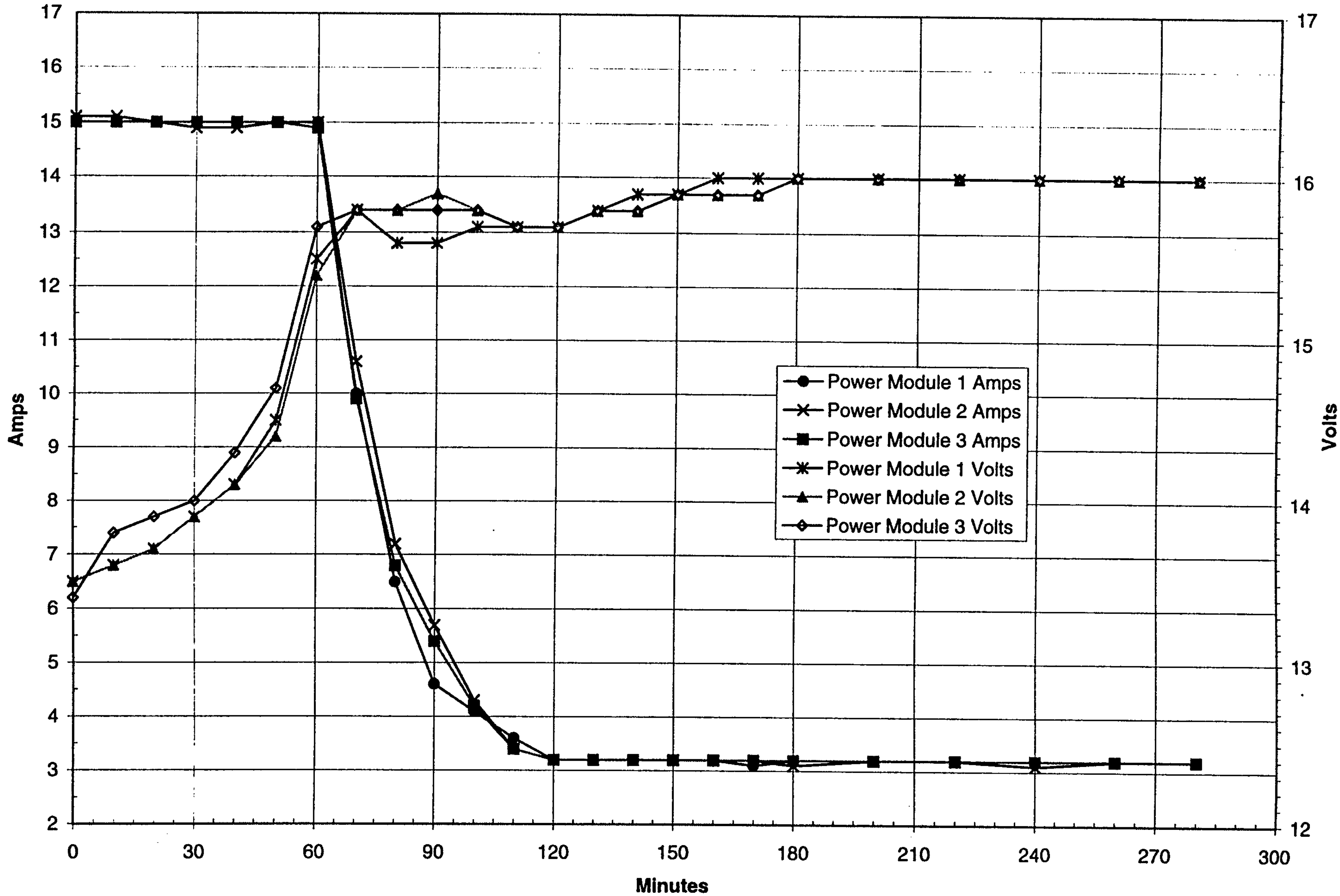

Power Module 3 Current Profile for 12-14-95 City-el Test of Mirabor Charger
Amps
Minutes
DAS Amps
Mirabor Module 3 Amps
Fluke Amps from Shunt
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0
30
60
90
120
150
180
210
240
270
300
330
360

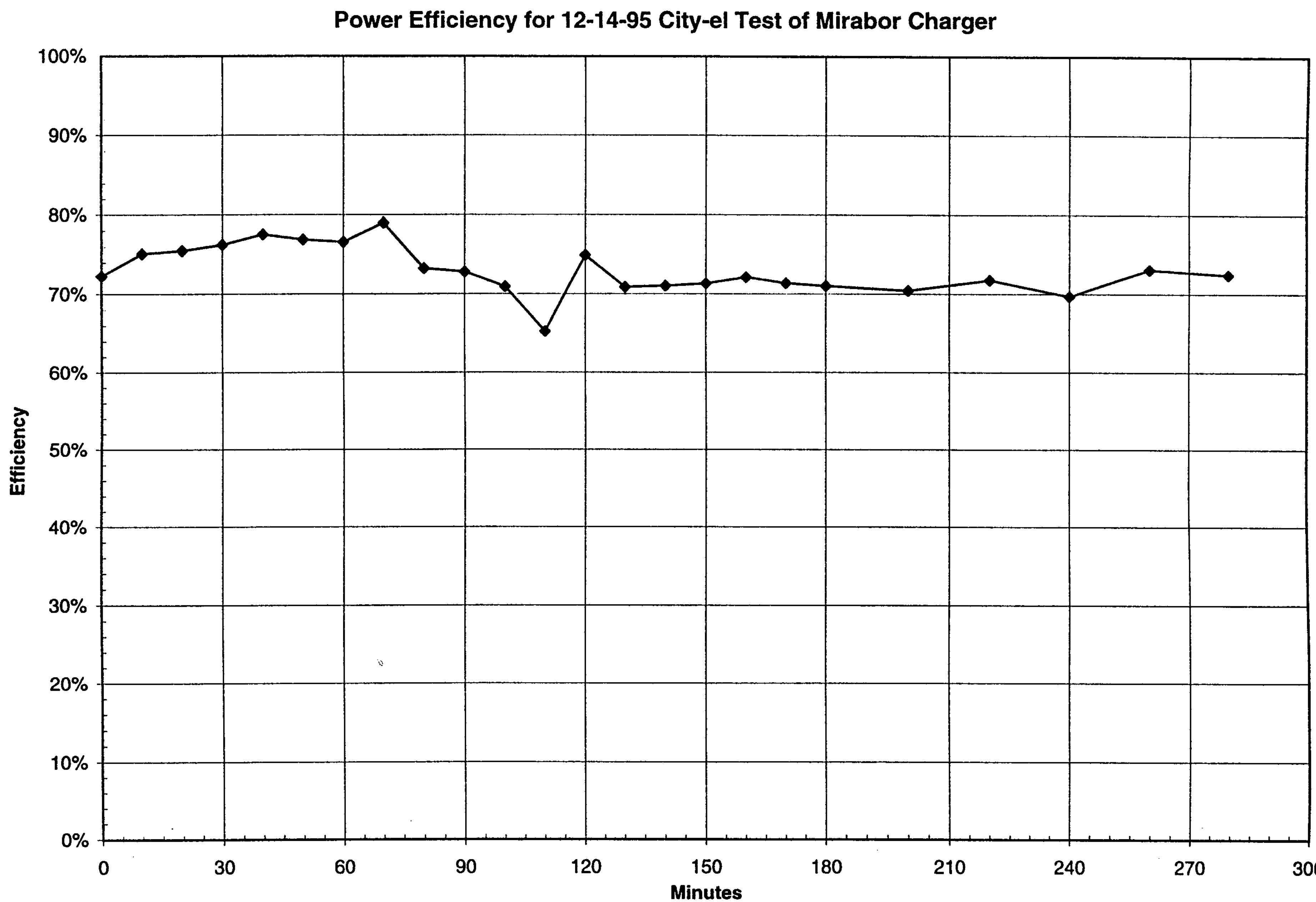
Power Module 3 Temperature Profile for 12-14-95 City-el Test of Mirabor Charger




Battery 3 Voltage Profile for 12-14-95 City-el Test of Mirabor Charger
Volts
17
16
15
14
13
12
0
30
60
90
120
150
180
210
240
270
300
330
360
Minutes
Power Module 3 Volts
Fluke Voltage on Batt 3

Mirabor Reported Voltages and Currents for Each Individual Power Module




Power Efficiency for 12-14-95 City-el Test of Mirabor Charger
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Efficiency
0
30
60
90
120
150
180
210
240
270
300
Minutes

Specific Gravity 45 Minutes After Charge.

Batt/Mod	Cell #	SG		Pack V
Battery 1 Module 1	Cell 1	1.275	+	+36V
	Cell 2	1.275		
	Cell 3	1.275		
	Cell 4	1.275		
	Cell 5	1.270		
	Cell 6	1.275	-	
				+24V
Battery 2 Module 2	Cell 1	1.265	+	
	Cell 2	1.275		
	Cell 3	1.275		
	Cell 4	1.275		
	Cell 5	1.275		
	Cell 6	1.275	-	
				+12V
Battery 3 Module 3	Cell 1	1.265	+	
	Cell 2	1.275		
	Cell 3	1.275		
	Cell 4	1.275		
	Cell 5	1.270		
	Cell 6	1.275	-	0V

To: Bill Warf, Pacific EV
From: Craig Ranta, Mirabor
Subj: Charger test

1/25/96

Bill:

Thanks very much for the test report. Great job, very thorough. When I saw the data about the temperature compensation being screwed up, I went back and re-tested your version of module firmware. It looks like there is a coding error which causes the modules to hold the batteries at the wrong gassing voltage. In my test unit, the temperature compensation seems to work, but the gassing (overcharge) voltage is too low. I'll troubleshoot this as time permits.

In the meantime, you can check the sensors by just holding them between your thumb and forefinger and observing the temperature display on the control head for the same channel. The AC power does not have to be on. If there are erroneous readings when the power is on, feel free to reduce the length of the temperature sensor wires to see if it cures the problem.

You can fool the modules by setting a lower battery capacity (i.e. 30-60 A-h instead of 130) to increase the gassing voltage. This is because the algorithm modifies the gassing voltage based on charge rate (because of internal battery impedance). However, this will reduce the equalizing charge current to about C/40.

The interference with the Cruising Equipment meter is a bit amusing. The modules are fairly noisy electrically, and the noise is very broadband (the switching frequency can vary from 15-40 kHz during a single AC line cycle). I think that their meter design skimped a bit on input filtering. After all, batteries and chargers are DC, right?

I changed 8-5 jobs. I now work as a hardware designer for Microsoft. I'm designing a wireless link for a new computer product. I met the big boss (Bill Gates, richest man alive) the first day. Perhaps I can talk him into buying a few Peregrins!

Hope all continues well; let us know if you need anything (other than working software).

Regards,

Craig

Charger Comparison Test, Data Sheet

Vehicle: 4126 Charger: MIRABOR

Trip

Date: 6/5/96 A C :0110376

DAS Filename: To home from shop 11AM TBD

Start Time: ______ DC Energy Start: ______ Amp-hr/W-hr

Hill Climb Time: ______ MILES 1726.7

End Time: 8:03 PM From home DC Energy End: ______ Amp-hr/W-hr

4 Dots remain 6 DOTS used forgot to Turn on Das 15 min

Charge

Charger seems to come on by itself and hang @ 3.2A until Charge screen is "entered"

Date: 6/5→6/6

DAS Filename: ______

Start Time: 8:09 P DC Energy Start: ______ Amp-hr/W-hr

End Time: ______ DC Energy End: ______ Amp-hr/W-hr

Disconnect Time: ______ 2.95 AC KW·h 113332

11.7 h

~~on charge~~ 1 = 12.7 2 = 12.7 3 = 12.6 V

State of Charge Measurements

Date: 6/6/96 Time: 2:30 PM

	Batt 1	Batt 2	Batt 3
Temp (deg. C)	28	28	28
Voltage	12.6	12.6	12.6
SG cell 1	1.260	1.275	1.265
SG cell 2	1.270	1.270	~~1.260~~ 1.265 wow
SG cell 3	1.265	1.275	1.275
SG cell 4	1.275	1.275	1.275
SG cell 5	1.275	1.270	1.270
SG cell 6	1.265	1.275	1.265

Note: Battery 1 is the left most battery as viewed from the rear. Battery 3 is the right most battery. Cell 1 is closest to the positive terminal, and Cell 6 is closest to the negative terminal.

Pacific Electric Vehicles: Phone: (707) 485-5799 FAX: (707) 485-[illegible]

Charger Comparison Test, Data Sheet

Vehicle: 4126 Charger: City-el

Trip

Started w/ almost 9 dots
2 ON at end

AC: 954368
~~[illegible]~~

Date: 6/6/96

DAS Filename: TBD

Start Time: ______ DC Energy Start: ______ Amp-hr/W-hr

Hill Climb Time: ______

End Time: 8:40 PM DC Energy End: ______ Amp-hr/W-hr

[illegible]

Mi: 1739.6

Charge

Date: 6/6/96

DAS Filename: ______

Start Time: 8:42 DC Energy Start: ______ Amp-hr/W-hr

End Time: ______ DC Energy End: ______ Amp-hr/W-hr 959010

Disconnect Time: ______

4.64 AC kW-h
7:53 AM
6/7 unplugged

State of Charge Measurements

Date: 6/7/96 Time: 4:30 PM

Batt 1	Batt 2	Batt 3
Temp: 29 deg. C	Temp: 28 deg. C	Temp: 29 deg. C
Voltage: 12.6	Voltage: 12.6	Voltage: 12.6
SG cell 1: 1.270	SG cell 1: 1.275	SG cell 1: ~~1.265~~ 1.270 [illegible]
SG cell 2: 1.265	SG cell 2: 1.270	SG cell 2: 1.270
SG cell 3: 1.275	SG cell 3: 1.275	SG cell 3: 1.275
SG cell 4: 1.270	SG cell 4: 1.275	SG cell 4: 1.275
SG cell 5: 1.270	SG cell 5: 1.270	SG cell 5: 1.270
SG cell 6: 1.265	SG cell 6: 1.270	SG cell 6: 1.265

Note: Battery 1 is the left most battery as viewed from the rear. Battery 3 is the right most battery. Cell 1 is closest to the positive terminal, and Cell 6 is closest to the negative terminal.

City-el Charger Comparison

Specific Gravity Readings

		Mirabor		City-el Standard		Zivan	
Pack V	Cell #	Before	After	Before	After	Before	After
+36V	Cell 1	1.220	1.290	1.220	1.300	1.215	1.280
	Cell 2	1.225	1.300	1.220	1.300	1.220	1.280
	Cell 3	1.230	1.300	1.220	1.295	1.220	1.275
	Cell 4	1.230	1.300	1.220	1.300	1.225	1.285
	Cell 5	1.230	1.295	1.225	1.295	1.225	1.280
	Cell 6	1.230	1.300	1.225	1.300	1.225	1.275
+24V	Cell 7	1.230	1.295	1.220	1.295	1.220	1.280
	Cell 8	1.230	1.295	1.225	1.300	1.225	1.280
	Cell 9	1.230	1.295	1.225	1.295	1.225	1.280
	Cell 10	1.230	1.295	1.230	1.295	1.225	1.280
	Cell 11	1.230	1.290	1.230	1.300	1.220	1.280
	Cell 12	1.235	1.295	1.225	1.300	1.225	1.285
+12V	Cell 13	1.225	1.290	1.225	1.290	1.220	1.270
	Cell 14	1.230	1.295	1.225	1.295	1.220	1.285
	Cell 15	1.230	1.295	1.225	1.300	1.225	1.280
	Cell 16	1.235	1.300	1.230	1.290	1.225	1.295
	Cell 17	1.225	1.295	1.225	1.300	1.220	1.285
0V	Cell 18	1.225	1.285	1.220	1.290	1.225	1.280
	Average	1.229	1.295	1.224	1.297	1.223	1.281

AC Energy Use

	Mirabor		City-el Standard		Zivan	
	Before	After	Before	After	Before	After
Hydria	130788	135913	1059044	1065056	0	0
AC kWh	4612.5		5410.8			

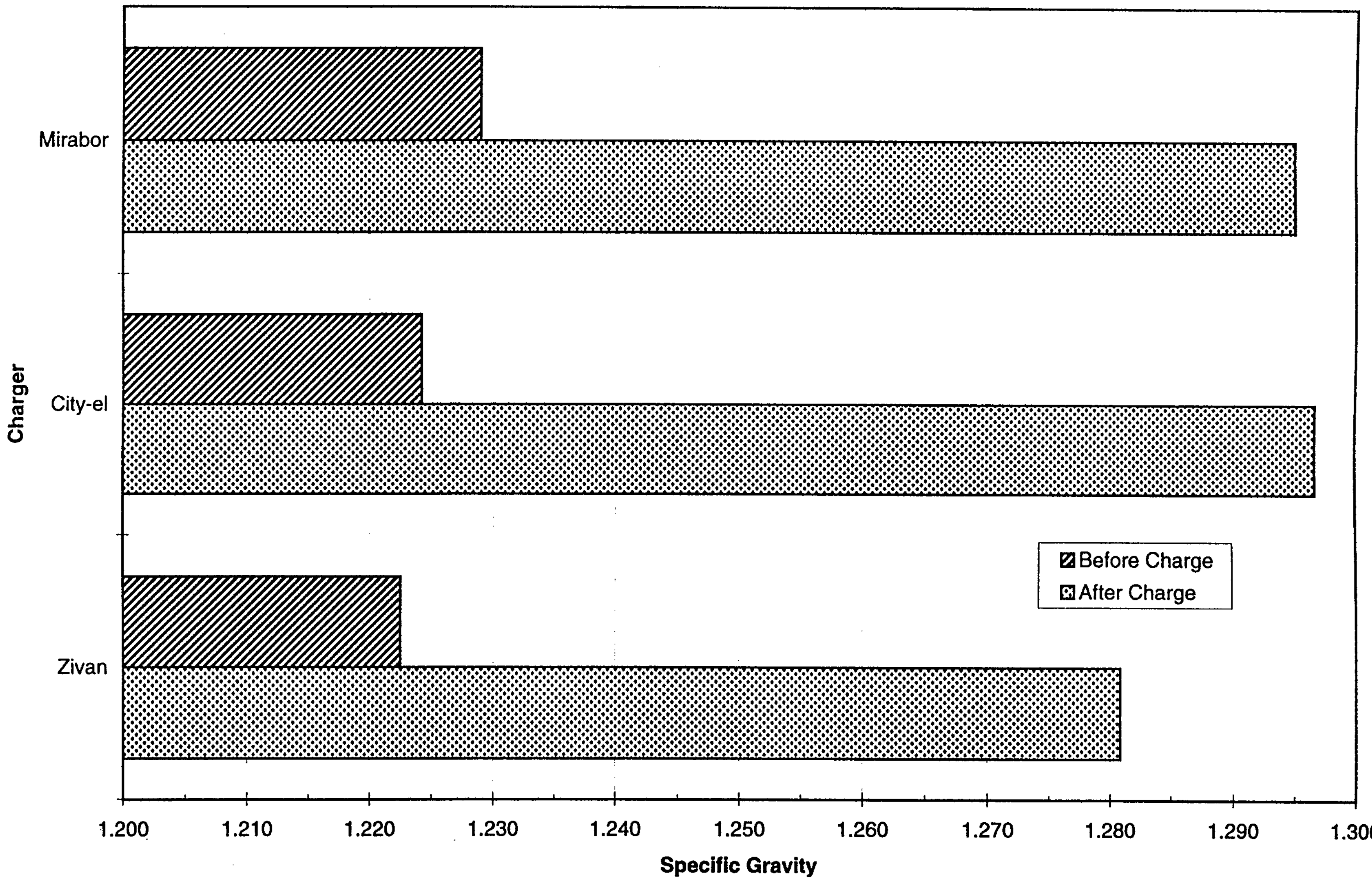
Specific Gravity Bar Chart Data

	Mirabor	City-el	Zivan
Before Ch	1.229	1.224	1.223
After Char	1.295	1.297	1.281

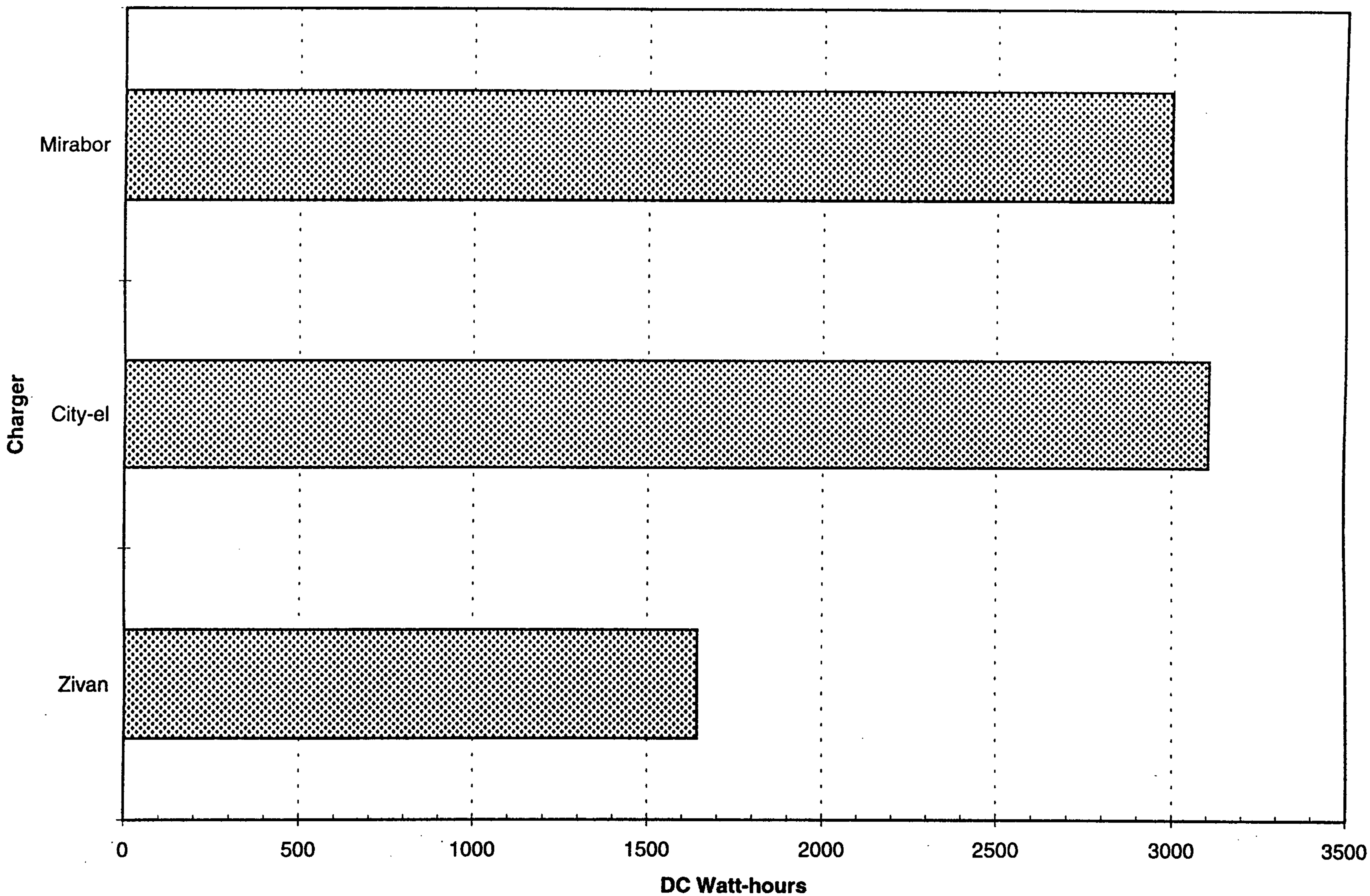
DC Wh Bar Chart Data

	Mirabor	City-el	Zivan
DC Wh	2998.994	3106.967	1643.42

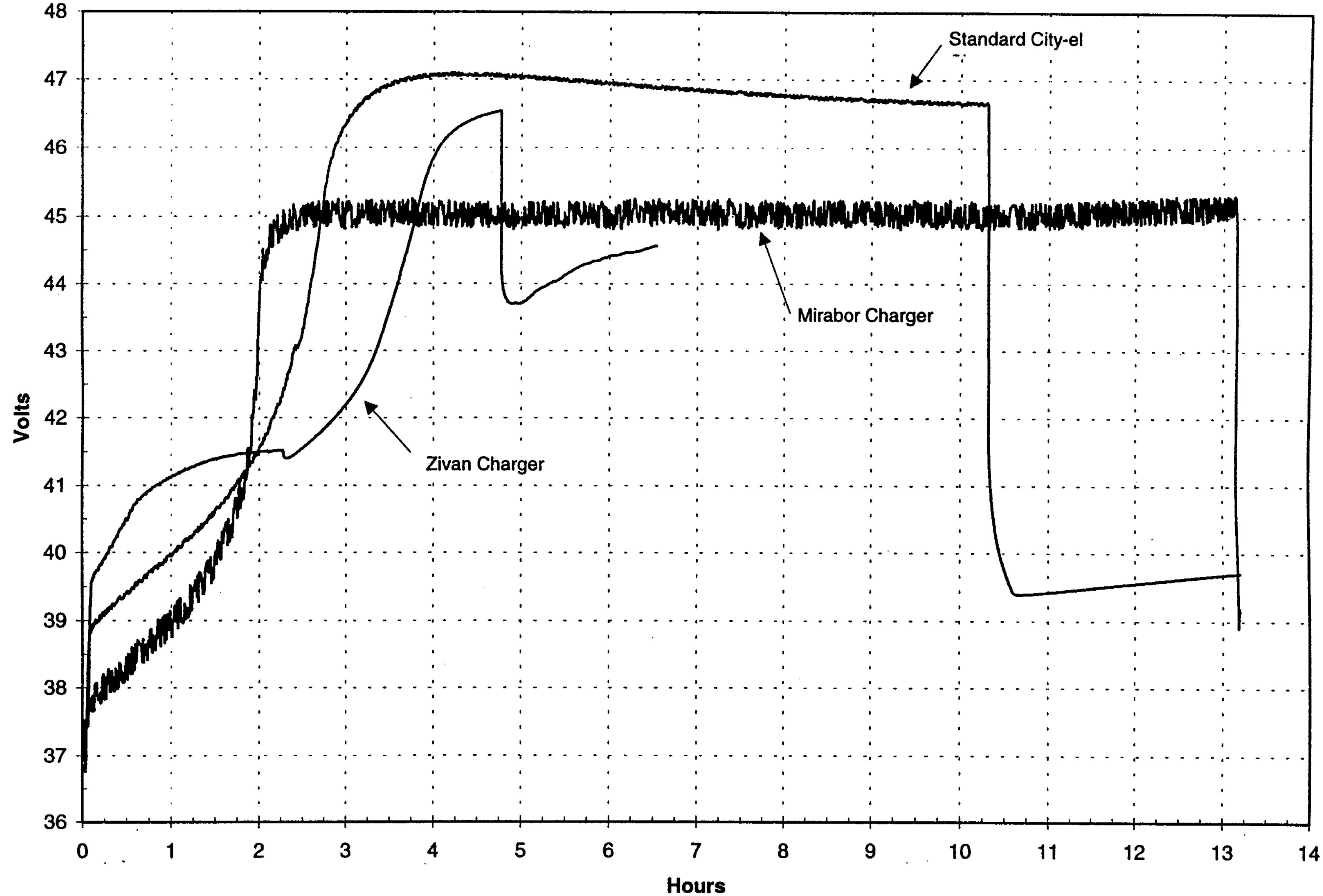
Average Specific Gravity of Cells in City-el 4126



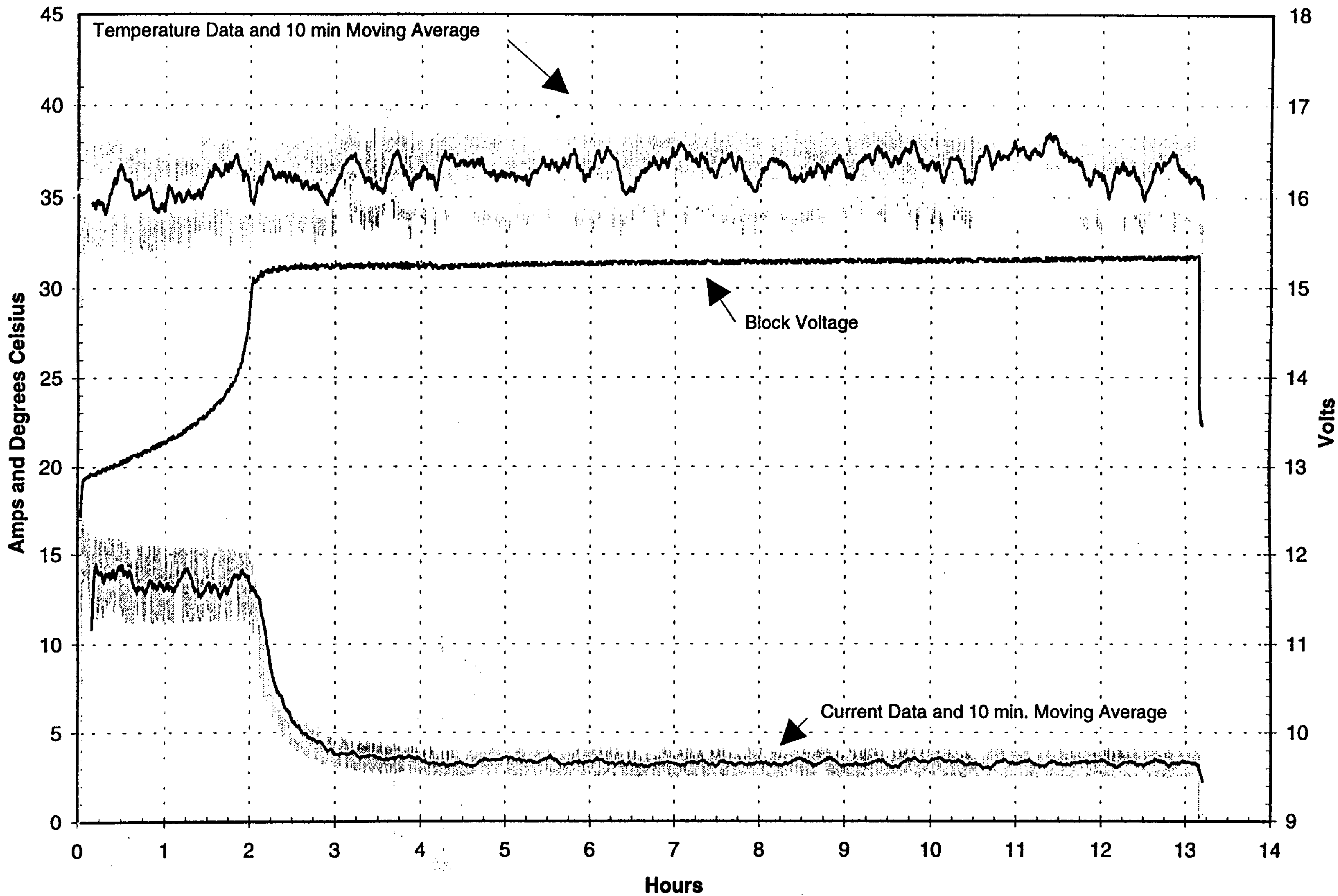
Total DC Energy Input to City-el 4126 Battery Pack



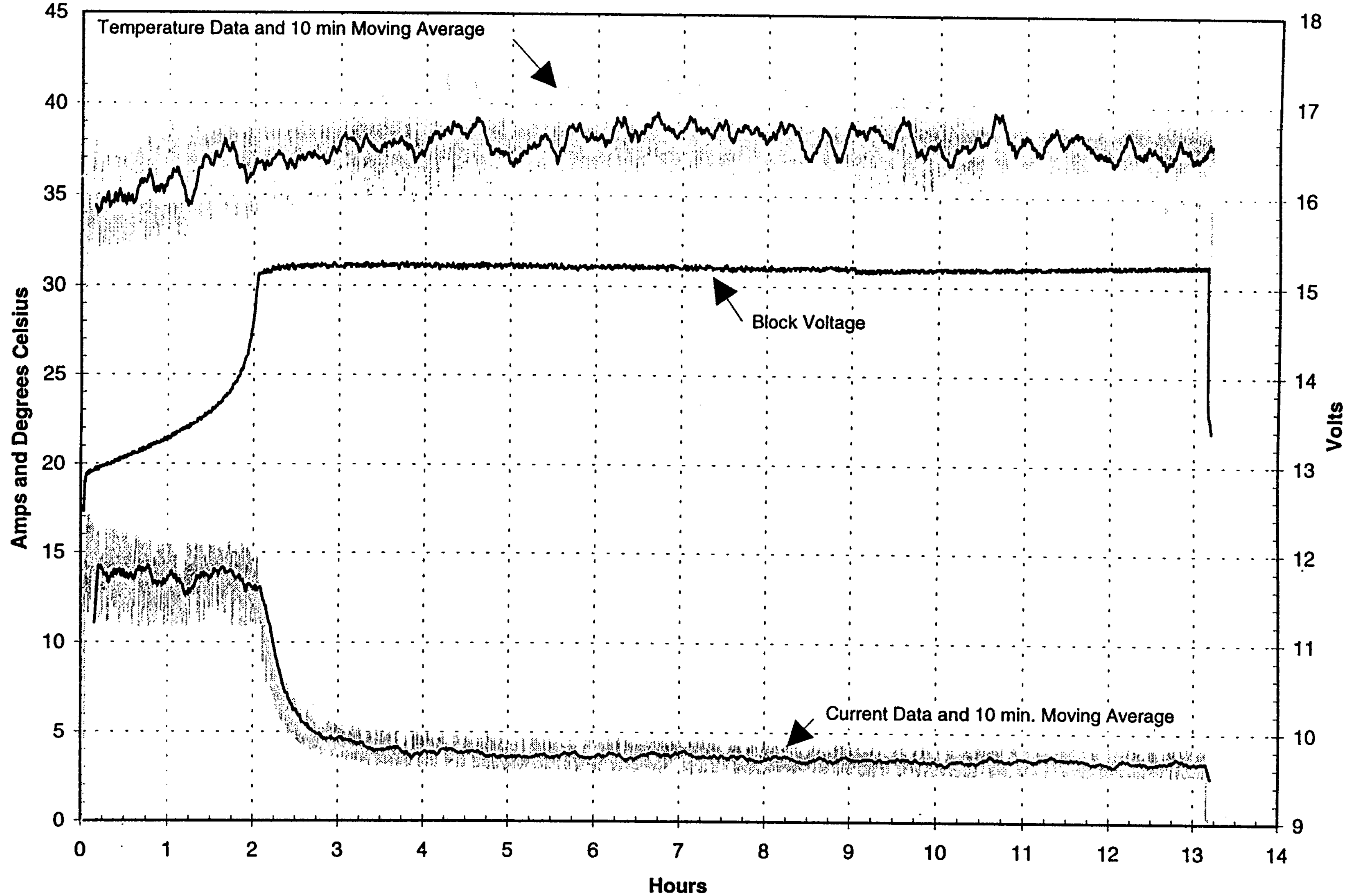
Comparison of Pack Voltages for Chargers Used on City-el 4126



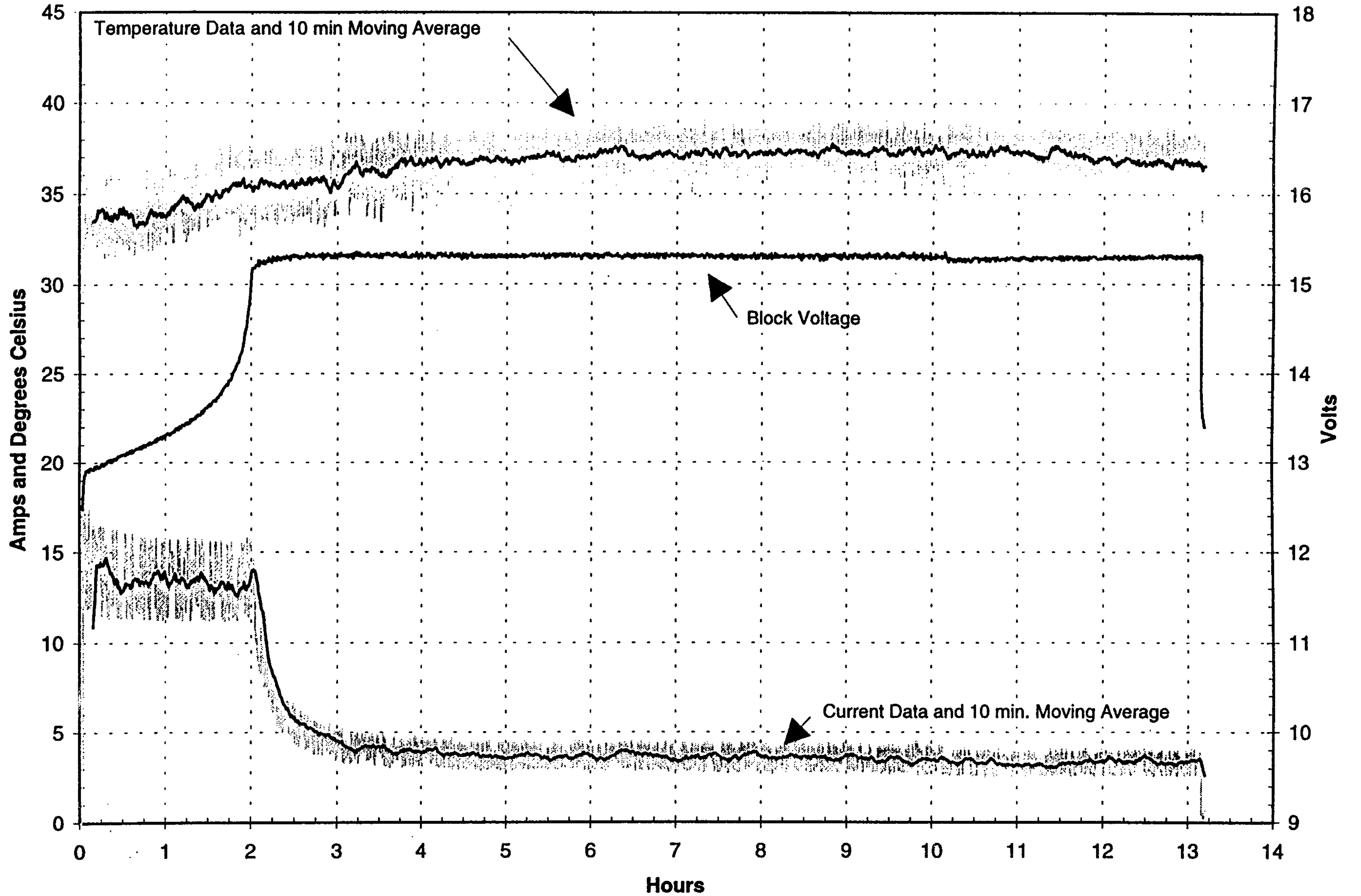
Charge Profile for Mirabor Module 1 on Battery 1 of City-el 4126



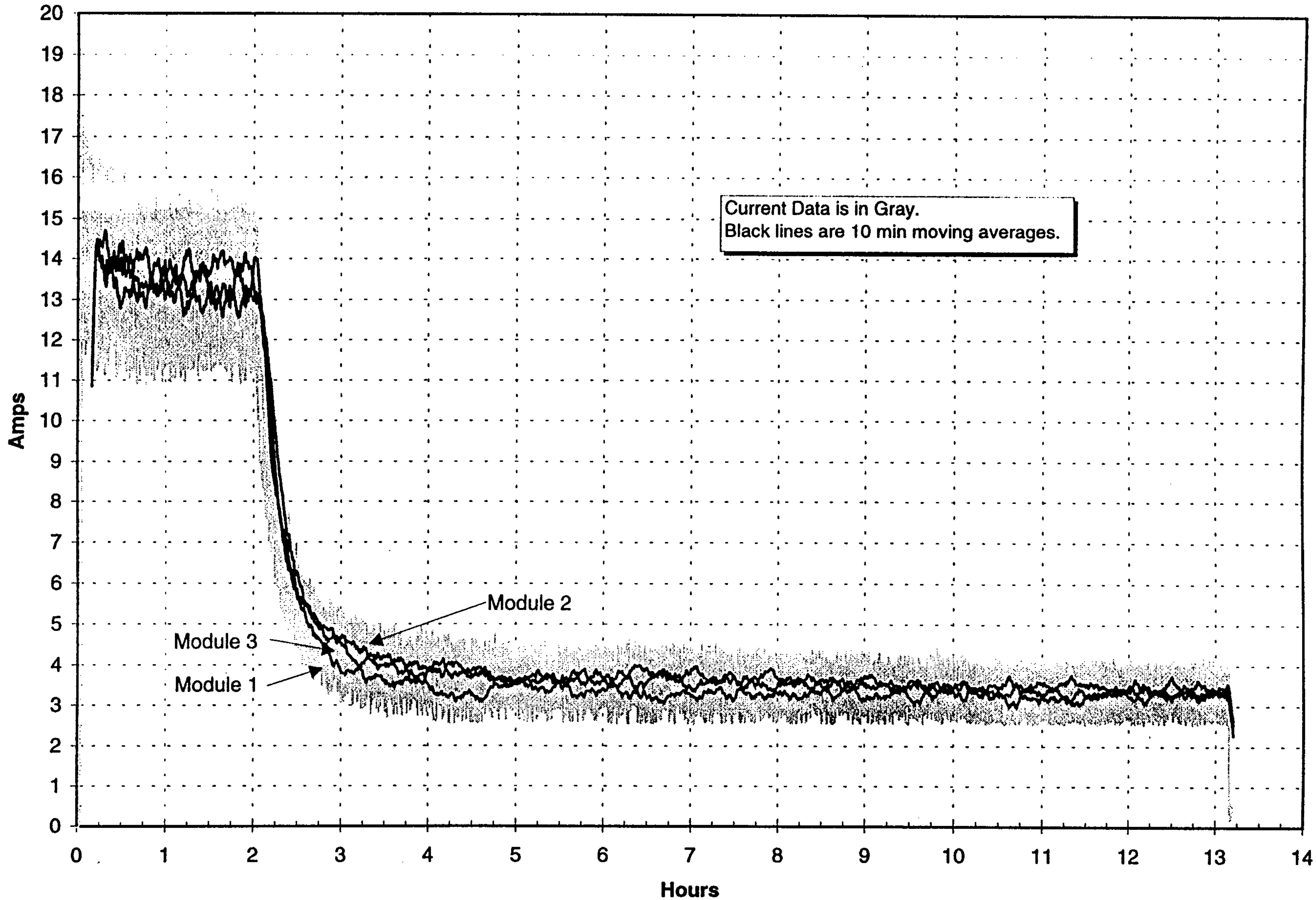
Charge Profile for Mirabor Module 2 on Battery 2 of City-el 4126



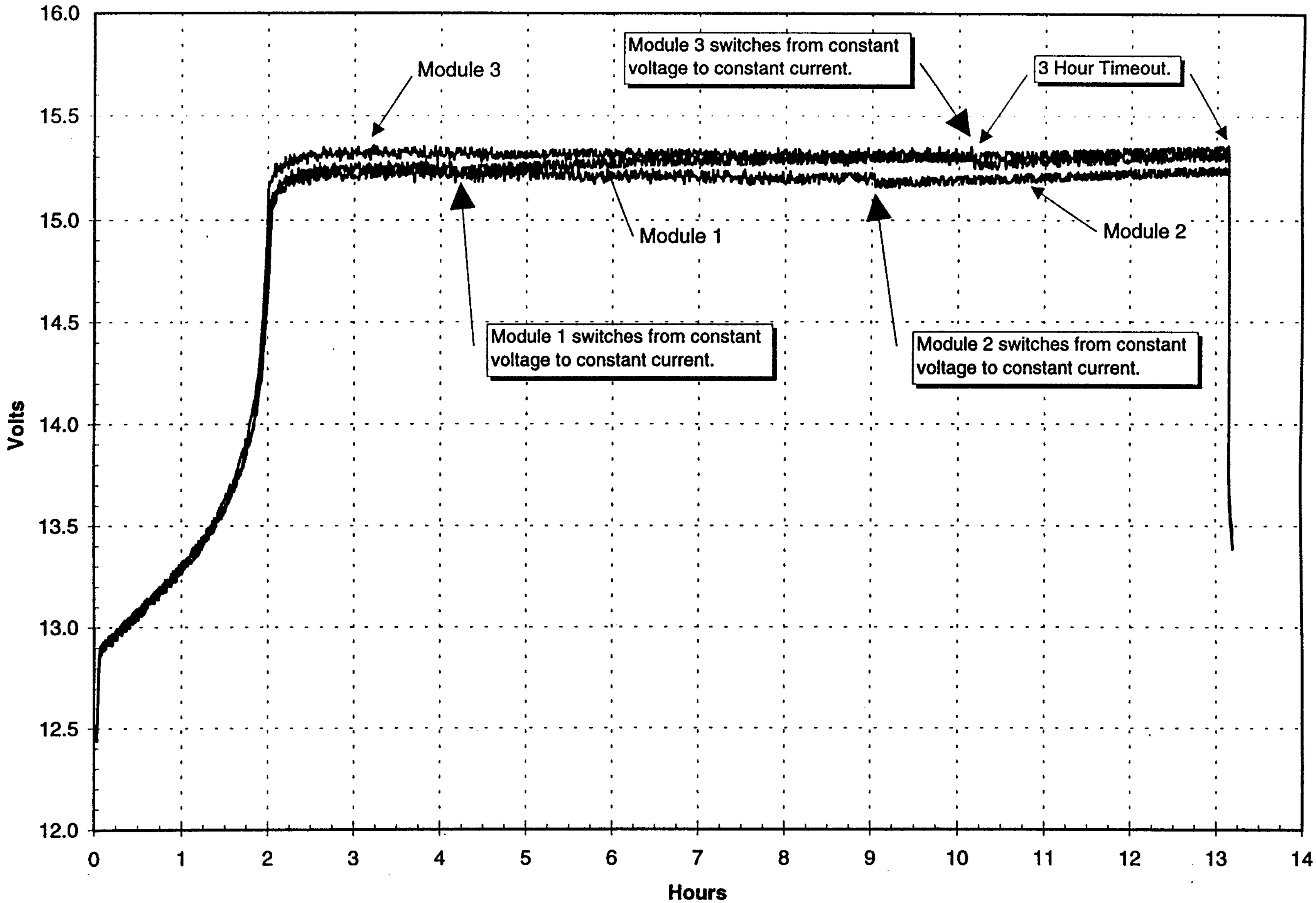
Charge Profile for Mirabor Module 3 on Battery 3 of City-el 4126



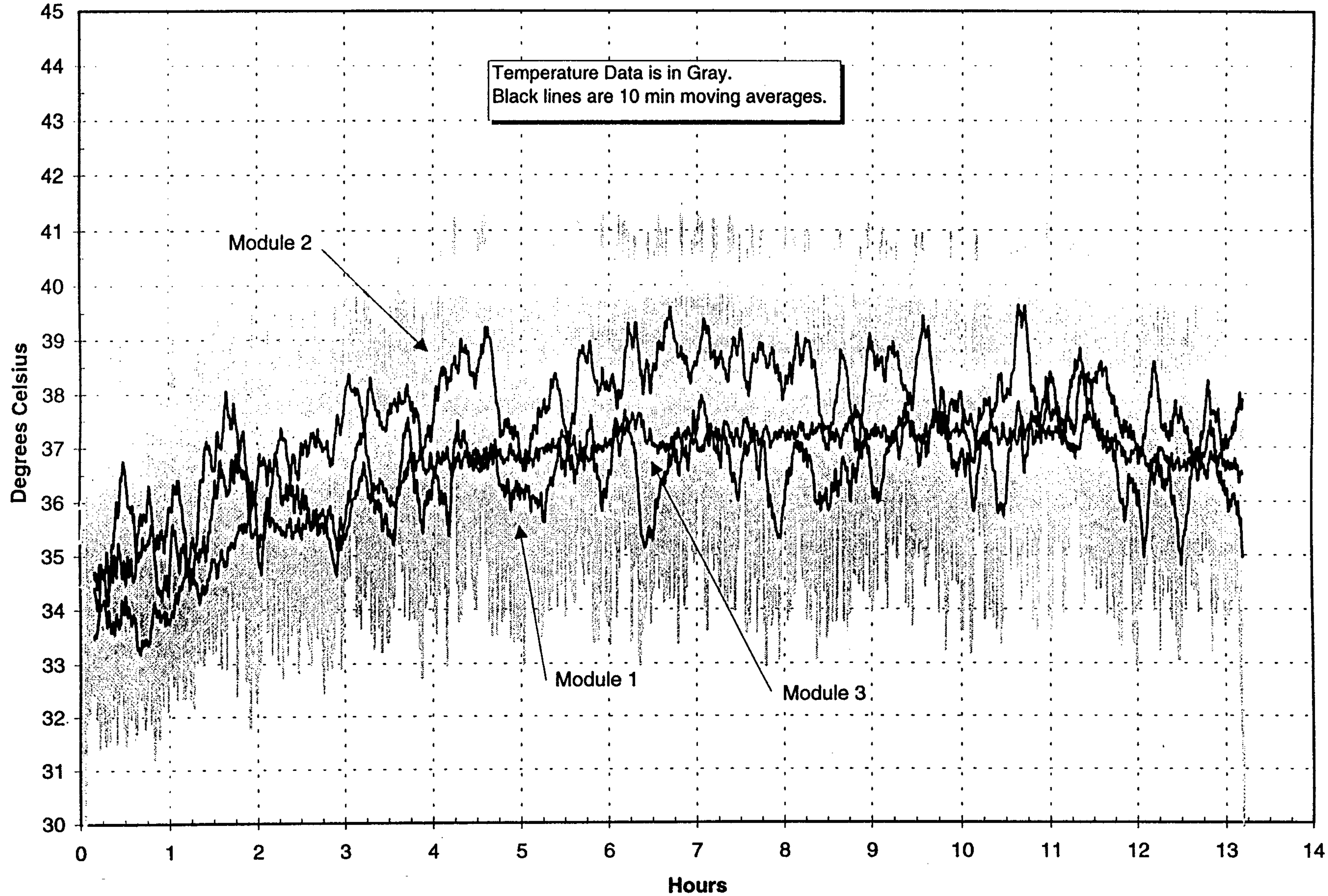
Comparison of Module Currents for Mirabor Charger on City-el 4126



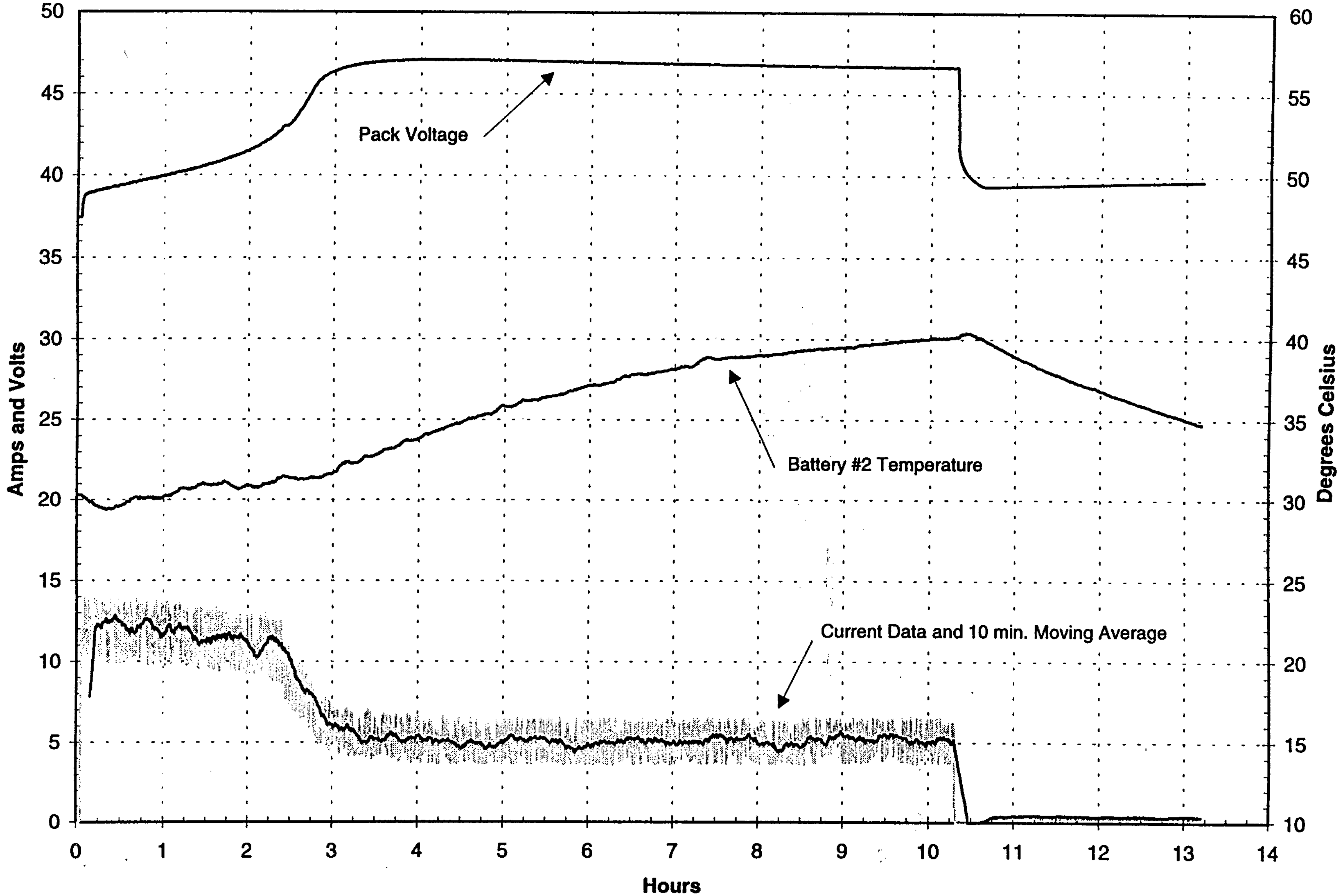
Comparison of Module Voltage for Mirabor Charger on City-el 4126



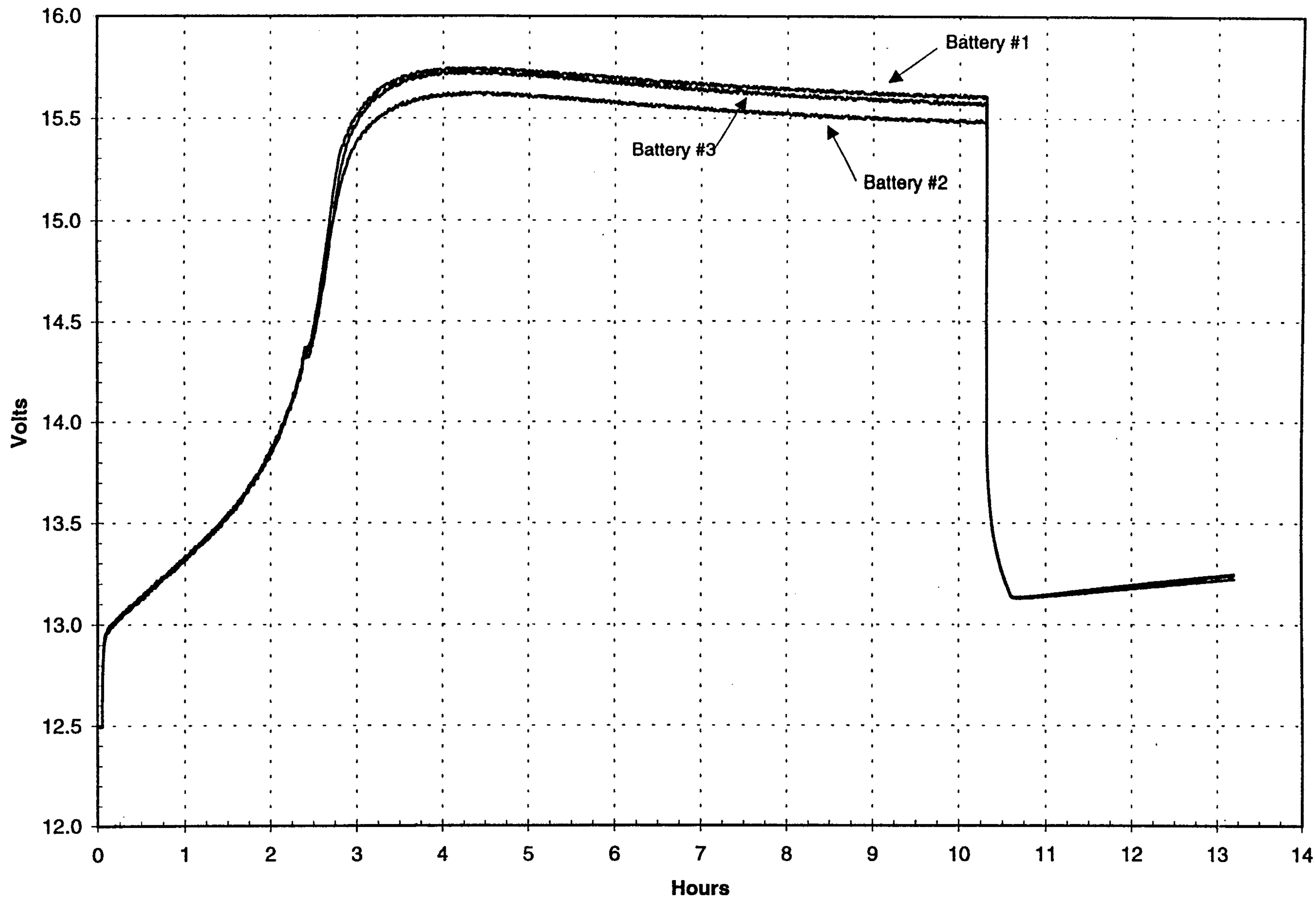
Comparison of Module Temperature for Mirabor Charger on City-el 4126



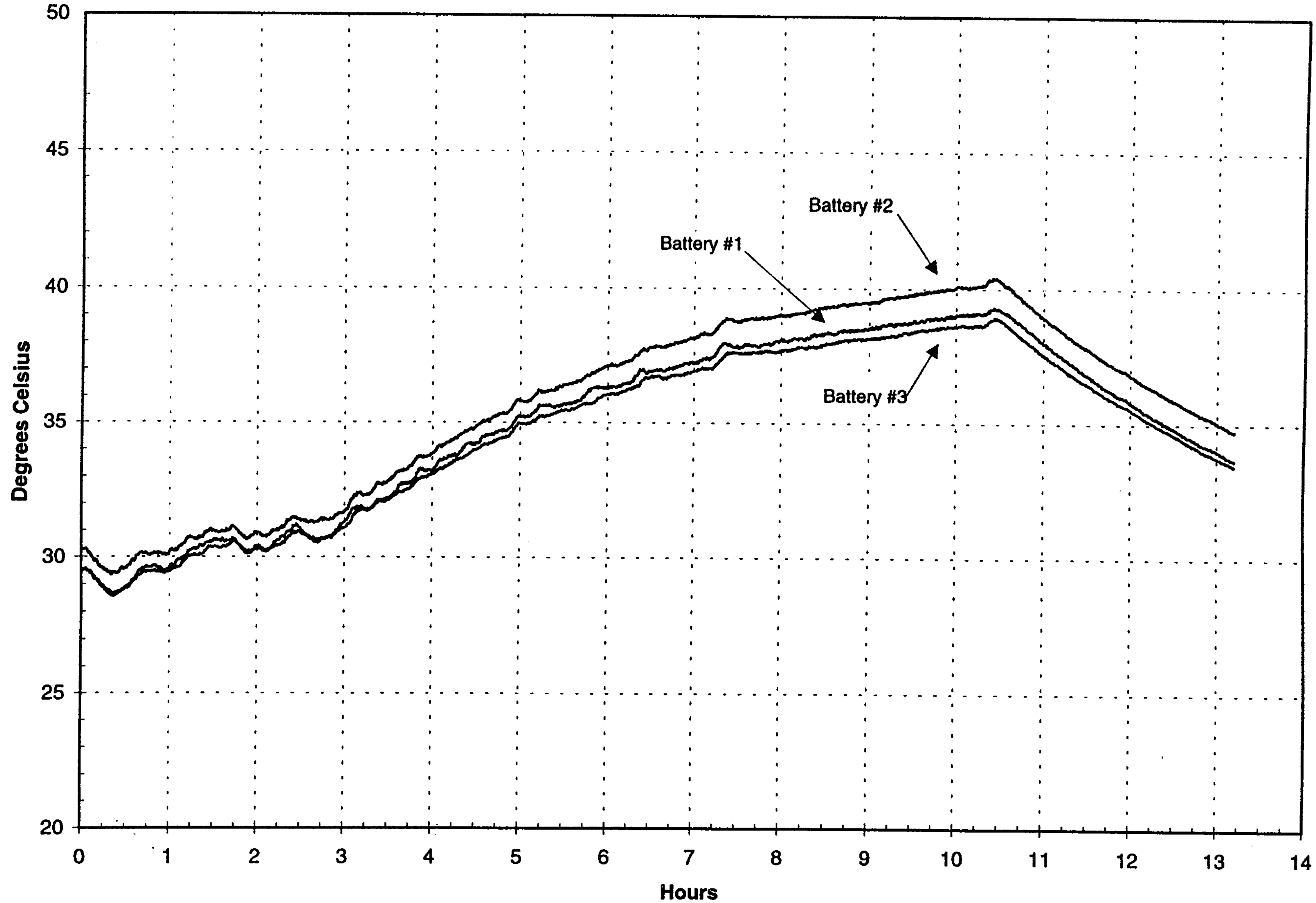
Standard City-el Charge Profile of City-el 4126

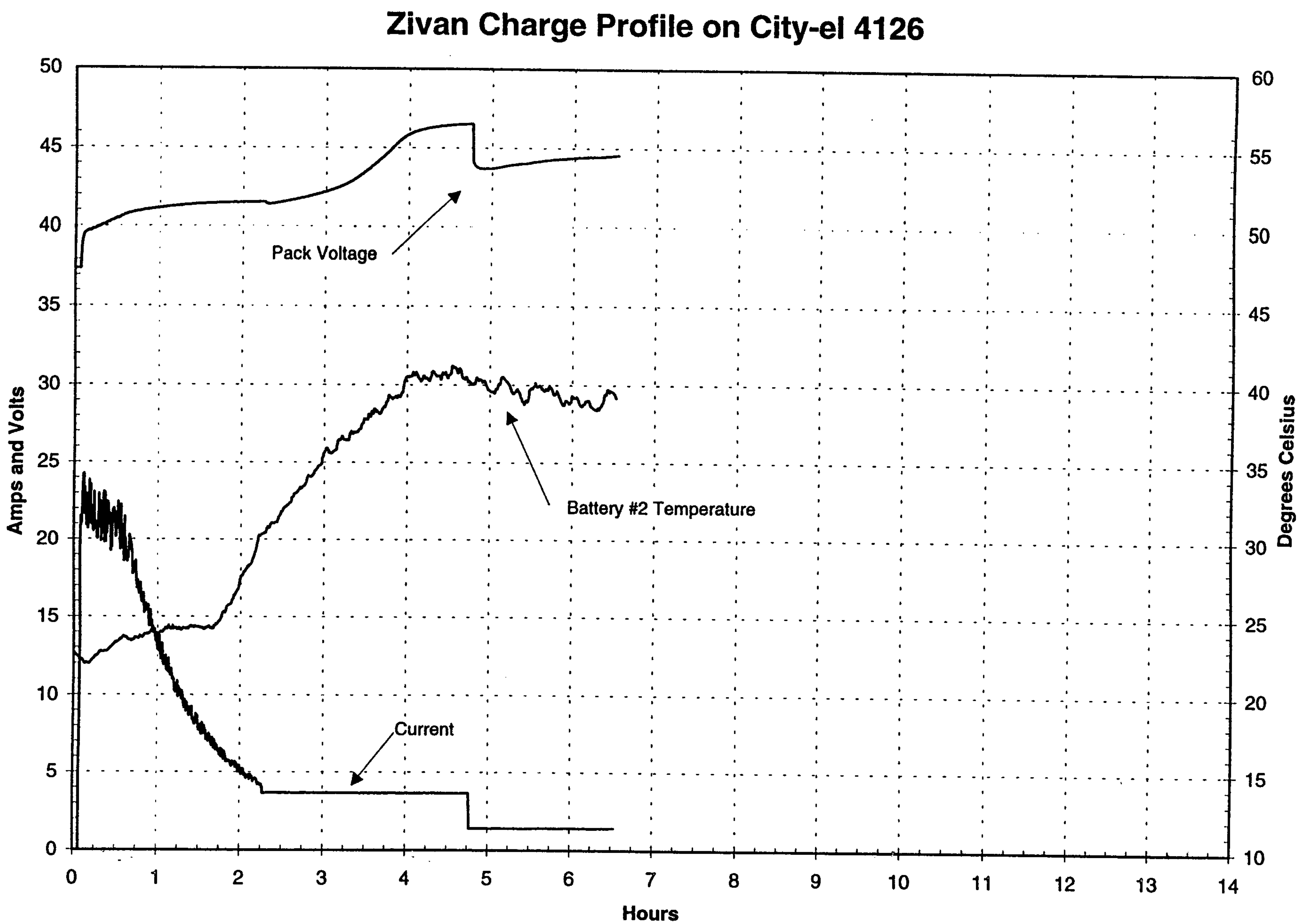


Comparison of Block Voltages for City-el Charger on City-el 4126

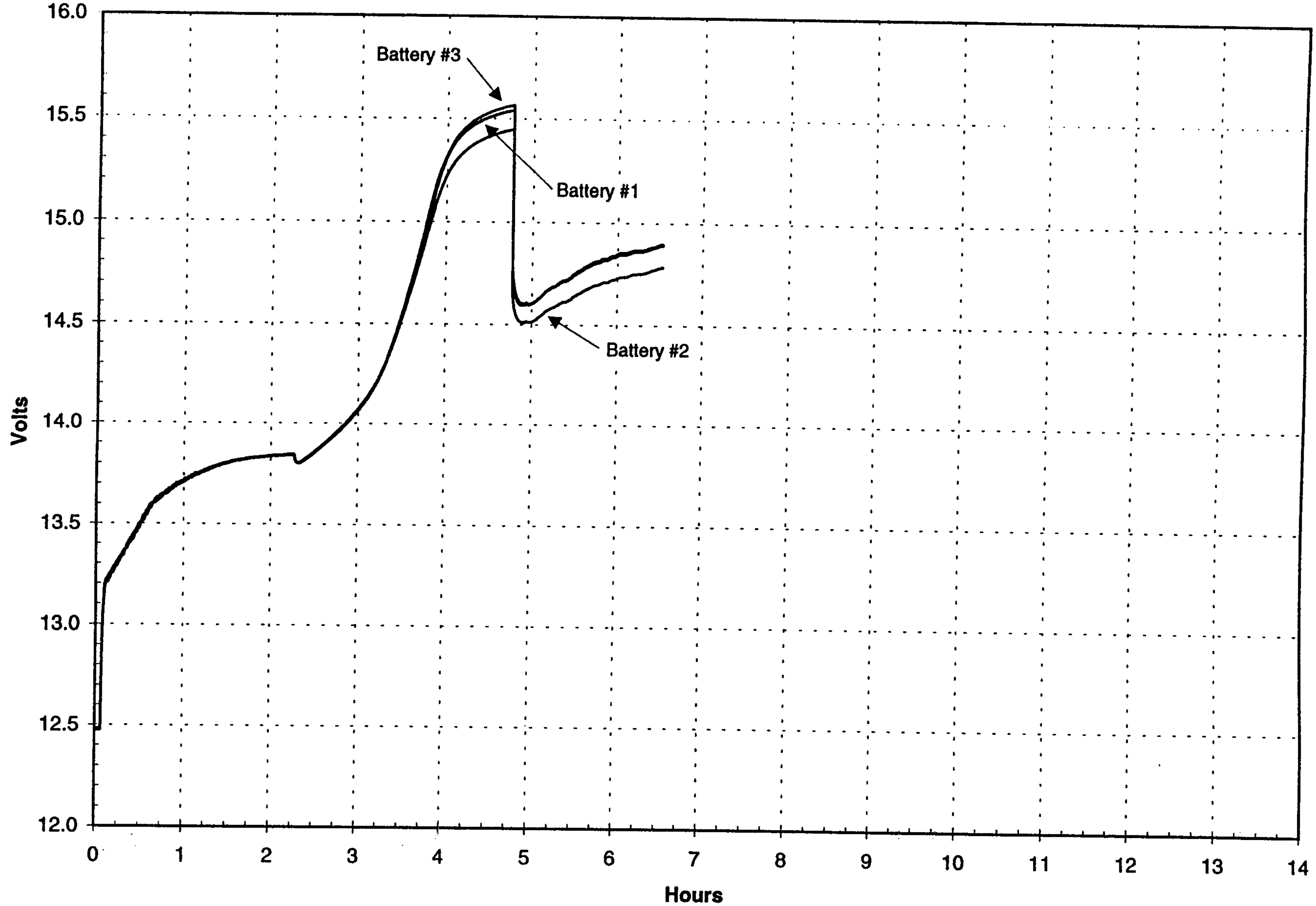


Comparison of Block Temperatures for City-el Charger on City-el 4126

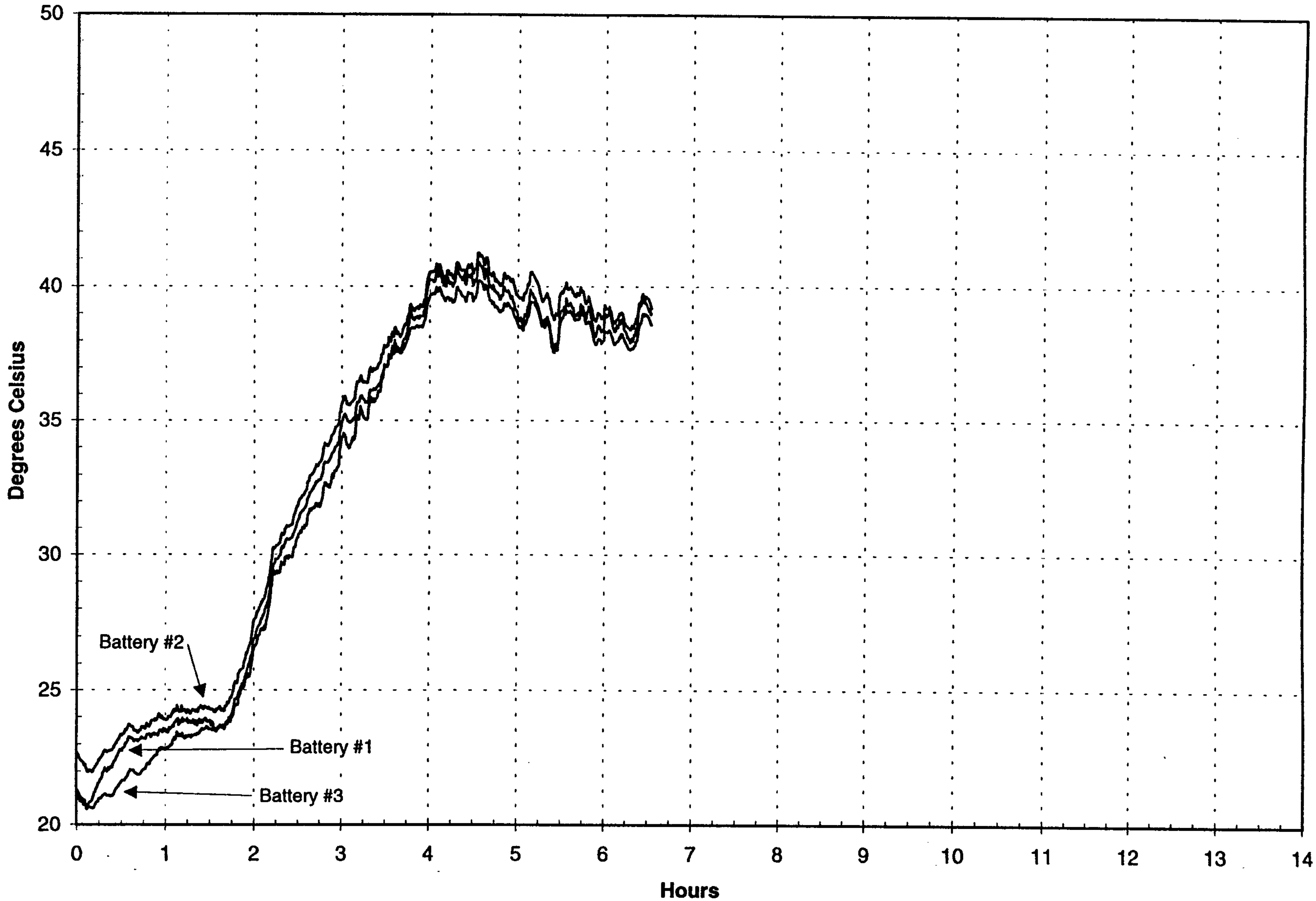



Zivan Charge Profile on City-el 4126
Amps and Volts
Degrees Celsius
Hours
Pack Voltage
Battery #2 Temperature
Current
0
5
10
15
20
25
30
35
40
45
50
55
60
1
2
3
4
6
7
8
9
11
12
13
14

Comparison of Block Voltages for Zivan Charger on City-el 4126



Comparison of Block Temperatures for Zivan Charger on City-el 4126



PEPCO TURBO-Z Charger Installation on a City-el, Final Notes

6 November, 1996

Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: William R. Warf

Pacific Electric Vehicles

This project is sponsored by DARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government and no official endorsement should be inferred.

PEPCO Turbo-Z Charger installation on a City-el, Final Notes

Scope:
This report provides a summary of testing performed to date on the PEPCO Turbo-Z battery charger. This charger is still in use on a City-el used by the Coast Guard at McClellan AFB. The vehicle for which the charger is installed is a 1993 City-el, Vin ...3999.

Background:
A complete test was performed on a 36 V TurboZ battery charger furnished by PEPCO in December, 1994. This test was documented in our document entitled "Test Report: PEPCO TURBO-Z charger use on a City-el", dated 12/31/94. An installation plan was prepared, titled "Consequences of Wiring for Long Term Use of the PEPCO Turbo Z Charger", dated 2/1/95. In August 1995, a location for a more permanent installation of the charger with a 220 Volt service was established, and the vehicle rewired for longer term use of the Turbo-Z. The installation included replacing the batteries with a new set of Trojan 30XHS batteries. Mileage at the time of installation was 451.5 miles. The installation was documented in "Final Wiring of the PEPCO Turbo-Z" report dated 4 August 1995.

Unfortunately, this installation was coincident with the end of our data acquisition effort, and we relied on others to maintain the Data Acquisition System (DAS) and collect data. As a result, very little DAS data was collected from the vehicle, and much of what was collected is incomplete or flawed.

Results:
The vehicle now has 827 miles on the odometer. The Turbo Z charger was used over the last year to support driving 376 miles. The attached data sheets show the vehicles batteries were often left uncharged or the vehicle allowed to self discharge.

The trip data collected with the DAS suggests that the users made a 3.2 mile round trip once a day, with a stop at the destination half way. A few trips of less than 1/2 mile were also recorded each month. The vehicle was probably driven only 8-10 days per month.

We estimate the batteries installed have about 168 cycles, or 12 cycles per month for 14 months. The batteries have not been replaced since the Turbo-Z was installed.

Collecting AC energy use was difficult with the reset-able AC Watt hour meter furnished by PEPCO, since it was never certain that the vehicle users would not reset it. Energy use lower than with a City-el charger was expected based on the test performed in December, 1994, but we are not sure what the actual energy use was. Since the vehicle was driven only 0.6 to 0.7 miles per day average in a month of 30 days, it is likely that much of the energy used was to replenish energy lost to self discharge, and not used for driving.

The TurboZ has been reliable and provided good service. The vehicle users in the Coast Guard building have conveyed a wish for a charger which can be carried with the vehicle, since this may allow more flexible use. The TurboZ would make a good fast charger for a small fleet of City-el's, however the use of this fleet would have to average more than 25 miles per day per vehicle for the charger to increase the usefulness of the fleet.

City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN SN-03999
Date 29 NOV. 95
Inspection by RC+JI

Start DAS download procedure: 10999 5333.150
Kilo-Watt hour meter reading = 203258
Odometer Reading = 539.5 (4.4)

Tires / Wheels	Pressure (as Found)		Tire Wear	Wheel Condition
Front:	(35 psi)	34	ok	ok
Left Rear:	(37-40)	36	ok	ok
Right Rear:	(37-40)	36	ok	ok

Jack up front of vehicle and check play in front wheel: —
Clean and Lubricate Clutch Disc: —

Batteries (if batteries appear nearly full check specific gravity.)

Water Added (in Liters): .12
Battery Appearance: ~~30x4~~ ok
Battery Type: 30x4 TROJAN

Left Battery: 1.180
Center Battery: 1.180
Right Battery: 1.180

Complete DAS Download: JI

Diagnosis Box

Voltage: 36
Dots: 0

State of Charge %: 82% 100%
12 Volt Light: Yes No
ETG Light: Yes No

Chassis Checks

Body Condition: ok
Lights Operation: ok
Brake Fluid Level: FULL
Window Washer Fluid Level: FULL
Plug in Charger and Verify Function: ok
Drive Vehicle: ok

NOTES: NOT CHARGED

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN SN- 03999
Date 2JAN. 96
Inspection by RC +J.J.

Start DAS download procedure: D9996 002. 150
Kilo-Watt hour meter reading = 040708
Odometer Reading = 544.6

Tires / Wheels	Pressure (as Found)		Tire Wear	Wheel Condition
Front	(35 psi)	34	ok	ok
Left Rear	(37-40)	36	ok	ok
Right Rear:	(37-40)	36	ok	ok

Jack up front of vehicle and check play in front wheel: —
Clean and Lubricate Clutch Disc: —

Batteries (if batteries appear nearly full check specific gravity)

Water Added (in Liters): .320
Battery Appearance: ok
Battery Type: 30XH TROJAN
Left Battery: 1.180
Center Battery: 1.180
Right Battery: 1.180

Complete DAS Download: J.J.

Diagnosis Box

Voltage: 35
Dots: 12
State of Charge %: 82% 100%
12 Volt Light: Yes No
ETG Light: ~~Yes~~ No

Chassis Checks

Body Condition: ok OLD CANOPY FLAG OK
Lights Operation: ok
Brake Fluid Level: FULL
Window Washer Fluid Level: FULL
Plug in Charger and Verify Function: ok
Drive Vehicle: ok

NOTES:

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN SN 3999
Date 5 FEB 96
Inspection by JACOB

Start DAS download procedure:
Kilo-Watt hour meter reading = 16346.5 WATT HOURS ON TURBO Z
Odometer Reading - 563.8

Tires / Wheels	Pressure (as Found)		Tire Wear	Wheel Condition
Front	(35 psi)	34	OK	OK
Left Rear	(37-40)	37	OK	OK
Right Rear:	(37-40)	40	OK	OK

Jack up front of vehicle and check play in front wheel
Clean and Lubricate Clutch Disc

Batteries (if batteries appear nearly full check specific gravity)
Water Added (in Liters): 0.5/0
Battery Appearance: GOOD
Battery Type: 30 XH TROJAN
Left Battery: 1.200
Center Battery: 1.200
Right Battery: 1.200

Complete DAS Download:

Diagnosis Box
Voltage: 35
Dots: 12
State of Charge %: 82% 100%
12 Volt Light: Yes No
ETG Light: Yes No

Chassis Checks
Body Condition: OK OLD CANOPY
Lights Operation: OK
Brake Fluid Level: FULL
Window Washer Fluid Level: —
Plug in Charger and Verify Function: —
Drive Vehicle: ✓

NOTES:

LOW VOLTAGE LIGHT BLINKS — ~~[illegible]~~

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN SN-03999
Date 5 MAR. 96
Inspection by RC + JJ

Start DAS download procedure: —
Kilo-Watt hour meter reading = 35291.2
Odometer Reading = 588.5 (24.7)

Tires / Wheels	Pressure (as Found)		Tire Wear	Wheel Condition
Front	(35 psi)	35	OK	OK
Left Rear	(37-40)	36	OK	OK
Right Rear:	(37-40)	36	OK	OK

Jack up front of vehicle and check play in front wheel: —
Clean and Lubricate Clutch Disc —

Batteries (if batteries appear nearly full check specific gravity.)

Water Added (in Liters): .22
Battery Appearance: OK
Battery Type: 30XHS TROJAN
Left Battery: 1.275
Center Battery: 1.275
Right Battery: 1.275

Complete DAS Download: —

Diagnosis Box

Voltage: 36
State of Charge %: 82% 100%
Dots: 0, YES, 0
12 Volt Light: Yes No
ETG Light: Yes No

Chassis Checks

Body Condition: GOOD, OLD CANOPY, FLAG GOOD
Lights Operation: OK
Brake Fluid Level: FULL
Window Washer Fluid Level: FULL
Plug in Charger and Verify Function: OK PEPCO
Drive Vehicle: OK

NOTES:

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN SN-03999
Date 26 Sept. 95
Inspection by = RC + JJ

Not Last Month had lost wh info. ZA

Start DAS download procedure: 0 999 5 269 . 150
Kilo-Watt hour meter reading = 19819.1   Running Total = 25089.2 ZA
Odometer Reading = 490.9 (18.1)

Tires / Wheels	Pressure (as Found)		Tire Wear	Wheel Condition
Front:	(35 psi)	34	ok	ok
Left Rear:	(37-40)	37	ok	ok
Right Rear:	(37-40)	34	ok	ok

Jack up front of vehicle and check play in front wheel: —
Clean and Lubricate Clutch Disc: —

Batteries (if batteries appear nearly full check specific gravity.)

Water Added (in Liters): .51
Battery Appearance: ok
Battery Type: 30XH TROJAN

Left Battery: 1.225
Center Battery: 1.225
Right Battery: 1.225

Complete DAS Download: J. J.

Diagnosis Box

Voltage: 36
Dots: 12
State of Charge %: 82% 100%
12 Volt Light: Yes No
ETG Light: Yes No

Chassis Checks

Body Condition: GOOD
Lights Operation: ok
Brake Fluid Level: FULL   Window Washer Fluid Level: FULL
Plug in Charger and Verify Function: ok
Drive Vehicle: ok

NOTES:

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

City-el Inspection Report   Neighborhood Electric Vehicle Program

VIN = SN-03999
Date = 29 AUG. 95
Inspection by = RC + JJ

Start DAS download procedure: D9995241.150
Kilo-Watt hour meter reading = 5270.1 PEPCO
Odometer Reading = 472.8 (29.2)

Tires / Wheels	Pressure (as Found)	Tire Wear	Wheel Condition
Front:	(35 psi) 34	OK	OK
Left Rear:	(37-40) 36	OK	OK
Right Rear:	(37-40) 35	OK	OK

Jack up front of vehicle and check play in front wheel: —
Clean and Lubricate Clutch Disc: —

Batteries (if batteries appear nearly full check specific gravity.)

Water Added (in Liters): .590
Battery Appearance: OK
Battery Type: 30XH TROJAN
Left Battery: 1275
Center Battery: 1.275
Right Battery: 1.275

Complete DAS Download: J.J.

Diagnosis Box

Voltage: 37
State of Charge %: 82% 100%
Dots: —
12 Volt Light: Yes No
ETG Light: Yes No

Chassis Checks

Body Condition: OK
Lights Operation: ALL OK
Brake Fluid Level: FULL
Window Washer Fluid Level: FULL
Plug in Charger and Verify Function: OK
Drive Vehicle: OK

NOTES: FIX FT BRAKE

August 21st Reset Button hit

mileage 470.4

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

City-el Service Report **Neighborhood Electric Vehicle Program**

VIN = 3999
Date = 8-2-95
Service by = Atkins
Odometer Reading = 451.5
~~Parts Used~~ KWH meter = 547738

Pepco Charger installation:
Batteries Replaced w/ 3 New Trojan 30XHSAP

NOTES:

Installed Plug on vehicle
Installed Relay for DAS and Drive disconnect while charging.
Charging shunt is heating up and "singing" while being charged.
By passed Capacity gage shut off
By passed charging shunt.
Placed Instruction sheet on charger
Placed Pepco owner's manual in vehicle.
Vehicle is missing RHT front canopy bolt. The one with the plastic nut.
Recalibrated DAS that got reset previously.

Pacific Electric Vehicles: Phone: (916) 381-3509 FAX: (916) 381-2189
Drive Electric Phone: (916) 442-5110 FAX: (916) 442-5110

Testing Notes, Persport #3,

60 Volt, Four Wheeled City-el
1 November, 1996
Neighborhood Electric Vehicle Product Test and Development Project

Prepared by: William R. Warf
Pacific Electric Vehicles

This project is sponsored by DARPA under Grant MDA972-93-1-0025, however the content of this document does not necessarily reflect the position of the Government, and no official endorsement should be inferred.

Persport #3 Testing Notes

Scope:
This report provides testing notes, specifications, and research results derived from driving and testing of the third four wheeled city-el constructed during the NEV project. Our purpose in construction of this vehicle was several fold:

1. Develop methods for construction of composite structures for the Peregrin NEV prototype.
2. Test suspension attachment to the composite structure
3. Experiment with the ride and handling of the four wheeled platform and a lower unsprung weight live rear axle.
4. Test a 60 V Solectria Brush Permanent magnet 6 hp motor drive.
5. Implement and test an improved steering system.
6. Test a 60V American Monarch battery charger.
7. Continue light electric vehicle market exploration with four versus three wheeled vehicles.

Reference Documents:
1. Persport vs City-el Comparison, 21 June, 1995

Background
Two four wheeled City-el's, #3344 and #3574 were delivered to SMUD on February 21, 1995. These vehicles were conversions of SMUD owned City-el's, and utilized the original City-el drive and rear axle. Construction of these vehicles involved removing the original front suspension and steering, bonding in a front suspension module to the nose of the chassis. Double A-Arm front suspension was used with Carrera adjustable ride height shock absorbers and a Honda 600 steering rack. The original City-el front wheel(s) are mounted to a special up-right spindle assemblies, which include a steering arm. The total front suspension module assembly weight was 60 lbs, and the unsprung weight was 18 lbs per wheel.

Testing of the first two four wheeled City-el ("Persport") vehicles was documented in our report Persport Versus City-el Test Report dated 6/21/95.

While the comfortable cornering speed of the four wheeled vehicles was an improvement over the original three wheeled vehicle, the steering felt heavy and it was hard to feel center. The rear suspension felt too stiff and rougher

riding than necessary. While the front suspension absorbed bumps well, the whole vehicle pitched when the rear axle went over bumps. We hypothesized that the problem with the steering was primarily due to steering linkage friction, and to low a steering ratio. Even with 4 degrees of caster, a 160 lb wheel load is easy to mask with friction.

The rear suspension problem was felt to be mainly due to high an unsprung weight, due to the 38 lb motor's fixed location on the axle, and the use of steel leaf cantilever springs. We also needed a platform to test a higher voltage drive.

Construction:
A City-el chassis (VIN ...4138) was selected, and the rear suspension, battery box, roll bar and front suspension were removed. A design was done for the battery box and rear suspension. This design used fabricated Aluminum trailing arms with mounting points for the original brake back plate, and coil over shock absorbers to mount the rear axle. The motor mount was modified to move the motor forward 10" to the front of the battery box. The motor mount was supported by a short link to the front of the battery box, which fixed the roll center of the rear suspension. Lateral axle location was accomplished with a Panhard rod. This geometry provided about 3/8" motor movement for 2.75" of rear suspension travel, and carried the motors mass at the short link at the front of the battery box. The ability of the motor fixed to the axle to rotate with the axle was retained, and allowed for the use of a chain drive without twisting the chain.

The battery box was fabricated using Ciba Aerolam Grade 5 aircraft flooring by the cut and fold method. Unfortunately three of the 5 batteries had to be located behind the rear axle because of the configuration of the City-el chassis. The battery box turned out to be an a rather elaborate structure. It was folded up and bonded into the chassis. Several layers of wet lay-up E-glass with Epoxy resin reinforced the structure. This structure proved to be relatively easy to fabricate, and it was decided that this method of fabrication would be acceptable for internal structures in the Peregrin NEV prototype.

Rear Suspension Mounting:
The trailing links were attached to the sides of the battery box through aluminum plates bolted and bonded to the sides of the box. The trailing links pivoted on spherical rod ends over 1/2 inch bolts. The bolts are cantilevered and transmit a bending moment into the side of the battery box. Shock absorbers with coil over springs are mounted into aluminum hat section bushings in the top of the battery box. The Panhard rod is attached to an L shaped bracket, bonded with epoxy adhesive, and clamped with bolts to the back of the battery box. Through out our testing these mountings have held up well, and there is to date no evidence of cracking, delamination, or other problems.

The rear suspension mounting on this four wheeled City-el is not as elegant as the system used for the front suspension of all three four wheeled City-els. It was decided to use independent suspension on the Peregrin NEV, with mountings to the composite similar to those used on the front suspension.

Steering, Ride and Handling:
The steering for this vehicle was modified from the first two vehicles by fixing the steering column to the chassis, instead of allowing it to pivot up with the Canopy top. The steering column was supported to a dash bulkhead fabricated from polystyrene foam, E-glass, and epoxy resin. This dash replaced the original City-el dash.

A short study of the geometry was done, and the most pragmatic modification found to be simply shortening the steering arms on the upright to increase the steering ratio.

These modifications increased the center feel feedback at the steering wheel, by decreased steering linkage friction and increased load from the same caster angle. The result was an improved on center feel of the system and a little quicker steering. We felt this was an improvement on the original design, and it gave us more information for design of the steering for the Peregrin NEV.

This four wheeled City-el has an entirely different handling feel compared to the first two four wheeled City-el conversions. The ability of the rear suspension to absorb bumps is substantially improved, with no loss of cornering capability. This was achieved inspite of the use of relatively stiff

springs necessitated by short travel. Our effort to reduce the unsprung weight worked. The vehicle did exhibit tail heavy behavior because of the batteries located behind the rear axle, and it is easy to spin in the wet using the regen pedal. The four bar linkage mounting of the motor fixed to the axle could be used for future in-expensive designs without incurring the high unsprung weight problem of the City-el design.

Drive:

A Solectria Brush Permanent Magnet motor and matched controller was used on this vehicle. A "decelerator pedal" arrangement provides very nice proportional control of regenerative braking. The five DC78 Trojan flooded cell lead acid batteries used to store energy for the system weighed 38 lbs each, giving a slightly lighter pack than the original City-el (190 lbs vs 198 lbs with three Trojan 30XHS). The DC78 batteries were not quite up to the task of providing up to 200 Amps to the drive, and the voltage could be pulled quite low on heavy acceleration (54 Volts or 1.8 volts per cell on a fully charged pack). This drive allowed gearing for a 42 mile per hour top speed, so this vehicle is about 5-7 miles per hour faster than the other four wheelers.

Driving the permanent magnet motor powered vehicle is different from a series or series compound motor. This drive provides fairly low torque up to a speed of about 15 mph, and then the motor begins to work and the acceleration picks up. When hills are encountered, the motor tries to maintain a constant speed, and simply draws more current. A chain drive was used with a ratio of 6.89 to 1 giving a top speed of 42 mph at 4500 RPM. The chain proved quite noisy, mostly defeating the quiet pleasure of driving a more refined EV.

This vehicle averaged 81 Wh/mile DC on the trip between my house and the shop, and full speed was used. This compares with about 75-84 W-h/ mile DC with a stock City-el, and 128 W-h per mile DC average with the original four wheeled City-el Vin 3344 for the same trip. The lower energy use at higher speed is attributable to the higher efficiency drive, higher voltage, regenerative braking, and better battery mass fraction of 33%. A stock City-el has a battery mass fraction at curb weight of 30%, and 3344 has a battery mass fraction of about 28%.

Range of the vehicle was about 20 miles best, if driven conservatively. "Pedal to the plastic" range was about 15 miles. Driven this way this vehicle is more comfortable on 45 mph speed limit roads than a City-el. It is almost fast enough for a rural commute.

American Monarch Charger:

A 60 V charger was obtained and used with 4138. The charger was a little large to carry in the vehicle, so it was often left in the garage. The vehicle was easily capable of the trip from my house to the shop and back. Some tests on this charger are covered separately. AC energy use for the vehicle has averaged 262 W-h/mile, with a best of 202 kW-h/mile.

Market Tests

It is very interesting to take City-els and four wheeled City-els to public events. At one such event an informal tally indicated people favor the four wheeled design over the three wheeler about 3 to 1. This may be partly attributable to the wider front track, but it seems to be indicative of a general preference for four versus three wheels.

Conclusions:

The four wheeled vehicle constructed on City-el Chassis 4138 has been a logical step in the development of an NEV design which would offer acceptable performance and comfort. The process of construction and testing of the vehicle contributed to the body of knowledge leading up to design and construction of the Peregrin.